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APPLIED MECHANICS REVIEWS

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THE MECHANICS OF ADHESIVE BONDING

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INTRODUCTION

Adhesive bonding has been employed for centuries, but its use has been restricted by the availability of only animal and vegetable glues, so that the structural uses have been confined to timber, and even then only to supplement dowel and pin fasteners. The spectacular exceptions were the bows used by Turkish and Mongol archers of the time of Genghis Khan (1) made by gluing together dissimilar materials to obtain a device capable of storing much more energy than the conventional wooden bows. However, all these early applications suffered from the susceptibilities of the adhesives to moisture, fungi and bacteria. The development in the 1930's of synthetic resin adhesives which were resistant to these conditions made possible the structural gluing of timber on a much more ambitious scale. The subsequent rapid development of other synthetic polymers with great strength opened the way to consideration of structural gluing of metals.

Some principal advantages of adopting bonding when mechanical fastening and welding have been in use for a long time include:

(a) A production cost saving which may result from the simplicity of gluing components together instead of using a large number of bolts, rivets or spotwelds.
(b) A reduction of the stress concentrations introduced by other means of attachment, e.g. at the edges of welds and at rivet or bolt holes, resulting in great improvements in fatigue endurance.
(c) Adhesive bonding induces less thermal distortion than does fusion welding because the curing temperatures are lower.

Other possibilities opened up are those where joining was previously difficult, if not impossible. Ultra-high-strength sheet steels cannot be welded without damage to the mechanical properties, and even if holes can be drilled, the joints may be of low efficiency. Therefore bonding is adopted where service temperatures permit. Dissimilar metals have in recent years been welded with difficulty; they can be bonded with suitable adhesives. Metals can be joined to non-metals, e.g. glass, wood, plastics, ceramics. Mechanical attachment of ceramics and crystals is simple with a cold-setting synthetic resin adhesive. Bolt attachments in timber structures are invariably inefficient, but good transport joints are made nowadays by bonding metal bearing plates to the wood. Much the same is true for reinforced plastic materials; a bond is easiest for a permanent join, and glued metal fittings are best if the joint must be dismantled. With fluid containers and some pressure vessels, bonded construction can avoid some of the sealing problems. There are, of course, problems associated with bonding, but the above are examples where bonding is found to be advantageous. While practically any solid substance may be stuck to another with some degree of success, this paper is hereafter concerned with adhesive joints, wherein either high strength is required, or the bond is essential to structural efficiency by virtue of its stabilising attachment.

ANALYTICAL ASPECTS

Lap Joints in Tension. Most of the theoretical effort has been devoted to lap joints. The first paper is generally accredited to Volkersen (2), but he was preceded by nearly 30 and 20 years respectively by Arnovlevic (3) "The distribution law of the adhesive stresses in bonded bars with axial loading," and by Fillunger (4) "On the strength of soldered, glued and riveted joints." Volkersen derived an analysis quite independently for the rivet load distribution of multi-row riveted lap joints in tension, where he idealized the rivets to be replaced by a continuous medium of given flexibility, and considered the case of a layer of glue. The significant parameter Λ from this analysis of a simple lap joint, in which bending of the adherends is neglected, relates their stiffness to that of the adhesive layer, and it is shown that shear stress concentrations occur towards the ends of the overlap, which depend upon this parameter. The analysis readily permits consideration of joints between adherends of dissimilar stiffnesses (i.e., thicknesses, or materials of different moduli), and is clearly applicable to double lap joints where there can be little bending of the adherends. de Bruyne (5) found good agreement with Volkersen using simple metal lap joints, and demonstrated the advantage of a bevelled lap, for which it can be seen intuitively that the stress concentrations would be relieved, since this is elastically equivalent to a scarf joint while retaining the offset. He also recognized that for comparing adhesive joints of different geometries (overlap and sheet thickness), Volkersen's parameter Λ could be reduced to a joint factor $\sqrt{s/l}$, since the glue line thickness should not vary appreciably between different joints. Further experimental confirmation comes from Hartman's tests (6) on double lap joints.

At about the same time as de Bruyne's paper, a rigorous analysis was published by Goland and Reissner (7) examining the normal stress distributions in the glue layer by permitting the lap joint to rotate due to bending of the adherends, which were assumed loaded remote from the joint. The analysis was con-

cluded for two distinct cases: (a) that of a thin rigid adhesive layer (i.e. most of the deformation occuring in the adherends), and (b) that of a flexible adhesive layer (containing most of the deformation). The former case is representative of well-fitting wood-to-wood joints, and the solution indicated maximum values of normal stress (both perpendicular and parallel to the joint) at the ends of the lap. The shear stress distribution had concentrations very near to the ends of the lap, but gave the correct value (zero) at the ends where a glue-air boundary cannot sustain a shear stress. Volkersen's analysis ignored this boundary condition. Goland and Reissner's second case is more applicable to gap joints and metal-to-metal joints, but this violated the boundary condition for shear stress as did Volkersen. The Goland and Reissner solutions are dominated by the bending moment factor K, which becomes reduced as the load on the joint is increased from zero, i.e., the bending of the adherends relieves the tensile stress concentrations at the ends of the overlap. This also means that the stress distribution for this purely elastic analysis changes with increase of load.

A simpler compromise solution was attempted later by Plantema (8) who modified Volkersen's shear stress concentration factor by allowing for the bending deformation of the adherends using Goland and Reissner's factor K, but neglected the normal stresses. When K is brought to zero, the solutions reduce to Volkersen's result. Sherrer (9) extended the analysis (7) to dissimilar adherends, using the same bending moments at the ends of the joint overlap, and obtained a series solution for the stresses. The shear stress boundary condition at the ends of the overlap was to be satisfied, but with the number of terms taken in the series, convergence could not be achieved. Cornell (10) considered a simplification of the Goland-Reissner method, in which the glue layer was idealized to a continuum of tension and shear springs, i.e. the effect of Poisson's ratio in the glue was ignored, as were normal stresses parallel to the joint.

Photoelastic analyses by Mylonas (11) on thick transparent glue lines between steel plates showed that the severity of the stress concentration depended upon the angle of contact of the glue to the adherends, as might be expected. In this work, the steel was thick relative to the joint length and much stiffer than the photoelastic medium so that the bending of the adherends was of a small order. Recent work at Glasgow by McLaren and MacInnes (12) using a composite photoelastic model with a lower modulus resin to represent the glue, largely confirms Goland and Reissner's results and has investigated external joint constraints in terms of values of $K < 0$ and > 1.0 (i.e. outside the range possible without such constraint). They demonstrated that the shear stress distribution could be fairly uniform as the theory would indicate for $K = -\frac{1}{3}$. The shear stress for $K = 0$ was shown to be still increasing within 1% of the lap length from the ends of the joint. Although the boundary condition must be satisfied in reality, this experiment suggests that the stress concentrations factors should not be greatly in error.

Scarf Joints. Elementary analysis indicated that there should be very small stress concentrations in a simple scarf joint. However, as scarf angles increase, the tensile stresses will be associated with lateral constraint, as described later with butt joints, while for most angles the problem of the finite shear stress at the boundaries recurs. It was discovered by Cooper (13) from strain measurements of the adherends that a shear stress concentration factor of 1.45 existed on a 6° scarf. A precise analysis developed by Lubkin (14) confirms experimental results. In scarf joints, the interaction of shear and normal stresses is more important than in lap joints, and experimental work on this aspect has been done by Hartman (6), Müller (15) and others. Lubkin has also considered in detail the problems of lands on scarf joints (16).

Butt Joints. This is the special case of a 90° scarf joint. Application of the theory of elasticity readily shows that the adhesive layer will be subject to lateral constraint unless both the adherends and the glue have the same ratio of Poisson's ratio to Young's modulus. In metal-to-metal bonds, the glue is of a lower order of modulus than the adherends, and since Poisson's ratio does not vary greatly, the glue will be subject to lateral constraint so that the stress distribution will depend upon the bond area dimensions and their relation to the glue thickness. de Bruyne (17) derived a relation indicating that for very thin glue lines the joint strength was inversely proportional to its thickness, and obtained experimental agreement. Another contribution on the strength of butt joints was made by Shield (18) using limit analysis.

Tubular Joints. Lubkin and Reissner (19) produced a thorough analysis for joints between overlapping tubes which allowed for radial contractions and expansions outside the joint, analogous to the bending Goland and Reissner considered for lap joints. For thick tubes, the results for the shear stress concentrations approximate to those of Volkersen. For tubular scarf joints, in tension or bending, simple application of the results for flat scarves appears to be sufficiently accurate, according to Perry (20).

Lap Joints in Edgewise Shear. An important case encountered in practice, particularly in aircraft, is that in which a wide lap joint is loaded antisymmetrically parallel to the lap. Since no appreciable bending of the adherends out of the plane of the sheet is involved, substitution of the sheet shear modulus for Young's modulus in Volkersen's formula appears realistic. This was suggested by Ljungström (21) and supported by test results.

Internal Stresses. It was appreciated from the earliest days of bonding metals that with a thermosetting resin adhesive, during cooling from curing temperature, stresses due to differential contractions between adherends and glue can arise. One case, that of an elastic block firmly attached to an undeformable solid, was considered by Aleck (22), who calculated the stress distribution at the interface due to thermal contraction. The important conclusion was that the greatest stresses occurred at the ends of the interface. Other sources of internal stresses are shrinkage during setting by the resin, and swelling due to moisture absorption as can occur in wooden and other laminates. This was analyzed approximately by Dietz, Grinsfelder and Reissner (23) for thin, rigid glue lines, and by de Bruyne and Mylonas (24) for deformable glue layers of finite thickness.

Peeling. Resistance to peeling is regarded as a necessity for structural adhesives, but the analytical work has been largely confined to the peeling or stripping of pressure-sensitive and similar adhesive tapes. Notable contributions have been made by Bikerman (25), Kobatake and Inoue (26) and Kaelble (27). Bikerman derived a formula for the minimum peeling load applied normal to a rigid backplate assuming linear elastic behavior. He later reworked the analysis for a non-Hookean adhesive where the stress was proportional to some power of the strain. The Japanese workers considered an elastic analysis for arbitrary peeling angles and verified by experiment the trend of decreasing peeling force with increase of peeling angle (180° peeling angle being "strip-back"). This result has been demonstrated for structural adhesives using practical sheet thicknesses by Ljungström (21). The Japanese analysis, and that of Kaelble, derives a "damped oscillation" distribution of normal stress, and Kaelble an exponential decay distribution of shear stress in the glue line.

A particular case was analyzed much earlier by Spies (28); that of the 'Redux' Peel Test, devised for the quality control testing of bonded aircraft structural components. He assumed an erroneous value for Young's modulus of the adhesive layer and derived a result for the mean peeling load that was of the

right order. However, he had assumed the glue to be elastic, and, as discussed later in this paper, plasticity of the glue layer is beneficial under peeling actions, and this was fortuitously covered by assuming a Young's modulus of about one-sixth the true value.

Other Solutions. Assuming Hookean behavior throughout, Goldenberg (29) analyzed the shear stress distribution in the glue where a spar angle is bonded to a load-carrying skin panel. He further considered the case of the spar angle flange's tapering in thickness and calculated an appreciable reduction in the maximum shear stress, which would be expected. Benthem and van der Vooren in the Netherlands (30) calculated with similar assumptions the stress distribution where top-hat section stiffeners are bonded to a sheet loaded in shear, the analysis indicating the contribution of the stringers to the shear stiffness of the sheet. Cornell (10) considered the case of a tab brazed or bonded onto a strip loaded in flexure, showing the magnitude of the stress concentrations possible at the end of the tab.

DISCUSSION OF PRACTICAL ASPECTS

Materials. Mechanical properties vary widely between the types of adhesives used for structural bonding. The following is an attempted classification of the commonly used types. All are thermosetting, requiring heat and often pressure for curing.

(a) Rigid, thermosetting type—mainly phenolic and epoxy resins, with Young's modulus in the range of 10^5-10^6 lb./in.^{2} Some of the resins may be fairly brittle.

(b) Tough, thermosetting type—usually containing a thermoplastic component. The Young's modulus and ultimate strength are of a similar order to (a), but the resin exhibits a much greater degree of plastic deformation before failure than does type (a).

(c) Rubber based—usually a formulation of phenolic resin with a type of synthetic rubber. The Young's modulus is low, of the order of 10^3-10^4 lb./in.,^{2} but the amount of plastic deformation at failure is small.

(d) Formulations with inert fillers—possibly based on phenolic or epoxy resins (a). The filling may be a metallic or other inorganic powder, which tends to raise the Young's modulus to the order of $1\text{-}2 \times 10^6$ lb./in.,^{2} reduce the coefficient of thermal expansion and impart some increase in the degree of plastic deformation before failure.

Some stress-strain curves are given in Ref. 31 for adhesives in categories (a), (b) and (c), and in Ref. 32 for adhesives (b) and (c).

Lap joints. The simple lap joint is the easiest type of bonded joint to manufacture and test, and while there remain doubts regarding the exact distribution of stress and parametric variations, comparative joints of fixed geometry (overlap, sheet thickness and material) are invaluable for comparing different adhesives, adherend surface treatments, and temperature resistance. Fortunately for engineers, it is laborious rather than difficult to test a fairly large number of simple joints to examine the variation of joint strength with sheet thickness and length of overlap. The measurement of adhesive elastic properties is not so easy, and the results may be not be consistent, as the last two references indicate. The mode of failure may be in shear or tension, as indicated by analysis, and may also occur either in the adhesive or at the adhesion interface. Plastic deformation of metal adherends will theoretically increase the stress concentrations, and certainly with fairly brittle glues, the associated tensile stresses may cause failure by peeling (of which, more later).

A further practical observation is that with lap joints of medium proportions ($\frac{1}{2}$ inch overlap in 0.064-inch structural aluminum alloy), although the tensile stress in the adherends is well below the yield, the bending moments outside the lap are sufficient to make the adherends simulate plastic hinges, and the joint be relieved by the rotation. Clearly the Goland-Reissner moment factor is then an overestimate of the effect of joint offset.

The plastic deformation which the adhesive layer can sustain before failure is of great significance. Of course this reduces the stress concentrations at the ends of the overlap and so the mean joint stress is improved. Such ductility also relieves the thermal stresses due to cooling. It is advantageous from this standpoint of thermal stress if the resin softening temperature lies between the curing and service temperatures. It is quite possible that a resin of type (a) with high heat resistance may exhibit an appreciably higher strength at temperatures between normal and softening because, at lower temperatures, the thermal stresses and lower ductility outweigh any increase in ultimate strength. This factor is important at extremely low temperatures where common plasticizers, particularly rubbers, themselves may become brittle. Some inert-filled formulations of type (d) possess great heat resistance, but possess strength at low temperatures due to improved ductility, and reduced thermal expansion coefficients. Artificial thickening of the glue line by the use of a glass cloth or similar resin carrier is often beneficial too, since this will permit the glue layer to take up a dimensional difference for a smaller strain. The type of fillet, or amount of squeeze-out at the ends of the lap, will depend upon the type of adhesive, and how much was applied. Mylonas (11) showed photoelastically that fillets affected the stress concentration, and it is found in tests to measure the bond strength normal to the glue layer that the squeeze-out has much bearing on the results. The significance of these various factors may account for the way in which test results (33) sometimes yield a better correlation by plotting joint strength against s/l (sheet thickness ÷ overlap length) rather than $\sqrt{s/l}$ as theory suggests. Heuer (34) considered the extreme case of plasticity in an adhesive by limit analysis which appears at first sight trivial, namely the shear stress is uniform. Such a case is encountered at elevated temperatures where, although the adhesive is quite serviceable, it is sufficiently plastic for this case to obtain, as indicated by joint strengths proportional to overlap and independent of sheet thickness (35).

As remarked earlier, structural bonding has been adopted on some aircraft for improved fatigue resistance. It has been demonstrated that a bonded overlap joint loaded in fluctuating tension may sustain nearly twice the fatigue load for a given endurance than can a well-designed riveted joint of the same overlap (36) (chosen for the latter) and therefore of equal weight. It is of no great significance that the ratio of fatigue strength to static strength is lower for bonded joints than riveted joints. For this order of overlap the static strength of the bonded joint would probably be limited by the tensile strength of the metal anyway.

Peeling. The property called "peel strength" is a measure of the adhesive system's ability to resist propagation of a local failure in the bond-line. Many "peel tests" have been devised to measure this peel strength quantitatively in which a thin flexible sheet is peeled or stripped from a more rigid backing surface to which it was originally bonded. The free end of the peeling strip is drawn away at a steady linear rate and the fluctuation of resistance measured autographically. In many cases, a peak force is required to initiate peeling, but after this initial failure, a significant force may or may not be evident. An advantage of a peel test is that the bond is examined over its whole bonded area. The ambiguous disadvantage is that whereas the mean resistance to peeling after the initial rupture is the quantity of interest, the length over which the mean should be calculated is subject to arbitrary definition. The bending moment in the peeled skin at the point of bond

rupture is important in the analyses and it is apparent that if the peeling is caused by a force applied to the peeled skin, the bending moment induced in the strip by the offset of the line of action will vary inversely with the peeling resistance, making the peel test very sensitive. This effect can be overcome by applying a rotary peeling action, so that the necessary torque is proportional to the peeling resistance. In both the initial and transient peeling configurations there is an acute concentration of stress at the current end of the glue line, and the peel strength is improved by the extent to which it can be relieved, i.e. by plastic yielding of the adhesive, or by its having a low modulus of elasticity.

The arbitrary nature of peeling tests and their sensitivity makes correlation of results from one test to another somewhat difficult, and quite empirical. Hartman (37) showed that there was no relation between peel and tensile shear test results. Peel tests will indicate differences in surface pretreatment of the adherends where lap joints will not. Because of the inherent scatter in peel results, careful applicaction of statistical significance tests is called for. It is observed, however, that the mere stripping apart of two identical thin metal strips (the simplest peel test) is not sensitive to surface pretreatment, because it only measures the cohesive bond strength, probably by its symmetry. It appears that the test condition for adhesive strength is asymmetry of stiffness, which then tests the adhesion to the thin adherend. The use of an adhesive carrier such as glass cloth is advantageous for peel strength, by helping to distribute the concentrations of stress.

STRUCTURAL APPLICATIONS

A brief mention might be made of a few mechanical problems associated with high-strength adhesive bonding. In a solid-fuel rocket case constructed from rings of ultra-high-strength sheet steel, a practical solution was achieved by bonding the cylindrical lap joints which sustained the longitudinal stress under internal pressure, using a low-modulus adhesive at the edges of the lap, and a stronger, stiffer adhesive for the center portion of the joint (38). This example of a lap joint occurring in practice is rare, although bonded joints in pipes are common. It is unfortunate for the subject that so much effort can be devoted to lap joints, whereas the practical uses are often not amenable to analytical study.

It is possible to manufacture efficient structural elements such as aircraft spar booms by bonding together metal sheet laminations instead of by forging or machining from the solid (39). For aircraft skin panels, a gain in efficiency is obtained over riveted panels by using bonded stiffeners which eliminate inter-rivet buckling and virtually achieve the desired case of skin-to-stiffener attachment at the line of the stiffener web, which gives maximum resistance to the wrinkling mode of failure. This is well discussed by Cox (40) and test results illustrate the improvements in static and fatigue strength of stiffened panels in compression (41,42). The current problem of aircraft design for safety with regard to fatigue draws attention to crack growth and crack stopping in a fatigue-damaged structure. Work by N.A.C.A. (43) has shown that the rate of crack growth with bonded stringers is slower than with other forms of construction, and tests in England (44) showed how much more effective was a bonded crack stopper strip than riveted or integrally machined ones. Evidently the lower stiffness of the adhesive helps to isolate the large strains at the end of a crack from the adjacent crack stopper, which can then prevent the crack spreading through the sheet to the next panel.

The advent of synthetic resins has permitted the development of another class of adhesives for metal sandwich construction, particularly that using a metal honeycomb core. In manufacture of this core material, metal foils are adhesive-bonded together to form a honeycomb, and then a slice of this material is bonded between thin metal skins, often with a film type of adhesive. By the use of a primer applied to the core, or by virtue of flow characteristics of the film when heated, a resin fillet is made between the foils and the facing skins, which are mutually perpendicular.

CURRENT PROBLEMS OF ADHESIVE BONDING.

The theoretical field will be better related to practice when the mechanism of adhesion is better understood. This is closely related to the physical properties of the adhesive polymers themselves which are inadequately represented in terms of a few elastic constants. Future joint analyses should cover the nonlinear stress-strain relations which are of greater significance than with metals. Nothing has been said in the main part of this paper of the rate dependence of mechanical properties. For decades, this has been recognized in the study of elastomers, and in the adhesives field it has been customary to note or standardize rates of loading without any significant deviations being observed through variations of testing rate. The mechanisms of crack propagation are not understood too well for most materials, and this appears important for rigid adhesives, and the seemingly rapid spreading of adhesion failure which can sometimes occur.

The better understanding of the physical properties of adhesives and adhesion may lead to a means of nondestructive testing for glued joints. Some instruments are fairly reliable for the cohesive strength of bonds, but adhesion strength cannot be assessed at present.

Fortunately, some excellent adhesives are available which permit metals to be joined without a great deal of calculation since the glue is "strong enough." With the need for greater heat resistance, the present normal temperature strengths in shear and peel cannot be achieved, and considerable structural research will be needed to estimate what reduction in these properties could be tolerated, while maintaining the present levels of structural integrity. Confidence will come from greater knowledge.

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Physics, General

Book—583. Stephenson, R. J., Mechanics and properties of matter, 2nd ed., New York, John Wiley & Sons, Inc., 1960, x + 367 pp. $7.50.

Book is a textbook for physicists written by a physicist. Differing from the engineers' curriculum, kinematics and not statics are used as introduction to mechanics. Contents: 1. Kinematics; 2. Force and motions of particles; 3. Work and energy; 4. Newton's law of gravitation; 5. Free and forced harmonic oscillations; 6. Motion of rigid bodies; 7. Properties of solids and liquids; 8. Statics; 9. Wave motion. Chapter 7, necessary for Chap. 9, gives a short introduction to some elementary problems of elasticity and a somewhat longer one to hydromechanics. The chapter on statics is also fairly short but well organized, as is the whole book.

The book intends to prepare the student of physics for more advanced work in his field, but may prove useful also for engineers who wish to supplement their knowledge of analytical mechanics.

K. Marguerre, Germany

Analytical Methods in Applied Mechanics

(See also Revs. 612, 617, 619, 631, 633, 643, 652, 660, 662, 680, 693, 704, 713, 720, 738, 740, 741, 774, 798, 807, 821, 835, 868, 892, 894, 898, 906, 911, 977, 1005, 1052, 1063, 1064, 1066, 1067, 1068, 1076, 1082)

Book—584. Duschek, A., and Hochrainer, A., Tensor calculus in elementary presentation, Vol. 1, Tensor algebra [Tensorrechnung in analytischer Darstellung, I. Tensoralgebra], 4th ed., Wien, Springer-Verlag, 1960, v + 171 pp. $5.70. (Paperbound)

Book gives a very clear exposition of the tensor algebra using the "analytic presentation," which means that tensors are denoted by a letter together with subscripted indices, the number of which determines the order of the tensor. In this respect it is not different from most modern texts on the subject. In the first 40 pages vectors are treated as first-order tensors, also with the analytic notation which gives the reader an opportunity to get used to this notation. Examples from geometry are given. In several places comparison is made with traditional vector symbolism of the Gibbs type.

Tensors of higher order are the subject for the rest of the book. Again the analytic notation is compared with older vector notation. Of interest here is the presentation of the vector product or "cross product" of vector algebra as an inner product of two vectors and a special tensor ε_{ijk} of third order.

Several exercises are given and there is a very valuable appendix giving solutions. Authors argue vigorously in favor of the analytic notation which, by using few almost self-evident operations, eliminates many special operation symbols. Reviewer agrees that this *may* be of advantage but it should be noted it is not obviously so in numerical work when computers are used. In such cases modern coding techniques may make it convenient to have an extensive set of special operators. [When there is a library program available for these operators there is no longer need to remember in detail how the operators are to be computed.]

In the introduction the authors present a severe critique against some applications of tensors. It is reviewer's belief that a textbook is not a correct place for such and also that the valuable recent development along the lines criticized might well have justified omitting this matter in this fourth edition. Also at several places in the rest of the text such critical notes of dubious values occur as, for instance, the statement that only when there is reason to talk about movements of a coordinate system should the name of a tensor be used. In all, however, this is one of the best introductory texts on tensor algebra known to the reviewer.

B. Langefors, Sweden

585. Weinzweig, A. I., The Kron method of tearing and the dual method of identification, *Quart. Appl. Math.* **18**, 2, 183–190, July 1960.

In recent years, Gabriel Kron has published a series of papers detailing his method of solving network problems by "tearing" the network into smaller subnetworks, solving the problem as pertinent to each component, then interconnecting the solutions to obtain a solution to the original problem. This technique initiated by Kron has been studied by a number of others [AMR **11**, pp. 203–206, May 1958].

The paper at hand "not only establishes the validity of the method but simplifies and extends it, and moreover, leads to a dual method we call the method of identification." The essential detail of accomplishing this is well-summarized in the author's words: "We first formulate a general network problem and establish a necessary and sufficient condition for the existence of a unique solution. This has independent interest for it simplifies and extends the Kron-LeCorbeiller mixed method of solving network problems. Following Weyl and Eckmann, an electrical network is considered as a one-dimensional cell complex and the problem formulated in terms of the chains and cochains of this complex. The solution of the problem is essentially effected by inverting a certain matrix, the matrix of the solution. The method of tearing (identification) transfers the problem to a second network obtained by tearing (making identifications in) the original network. There the solution matrix is inverted by inverting two matrices, the component matrix and the connection matrix ("interconnecting the solutions"). Although the rank of the component matrix is greater than that of the solution matrix, it is strongly diagonal and can be inverted by inverting each of the diagonal submatrices ("solving the problem on each component"). This is actually a special application of a more general procedure developed in Sec. 8 whereby the solution matrix is inverted by inverting two other matrices, the first of rank greater and the second of rank less than the solution matrix. If the inverse of the first is known or for some reason more easily computable (as in the case of tearing and identification) then this leads to a simpler solution. This also furthers Kron's goal of "storing solutions."

The reviewer recommends detailed study of this paper to the attention of all who have found interest in the theory of tearing and diakoptics.

T. J. Higgins, USA

586. Salles, F., Roots of an algebraic equation depending on a parameter—application to the stability and guidance of missiles (in French), Publ. Scient. Tech. Min. Air, France no. 351, 69 pp., 1959.

Consider an algebraic equation of the form $n(p) + Kd(p) = 0$, where p is a variable, K a variable parameter, and $n(p)$, $d(p)$ are polynomials in p. Author proposes to study the curves representing the loci of the roots of this equation in the complex plane when K varies between $-\infty$ and $+\infty$.

The first chapter is concerned with the locus of the roots in general, its asymptotes and tangents, its intercepts with the coordinate axes, and with the particular cases when the locus is a straight line or a conic. This theory is then applied to servomechanisms and hydrodynamics. The locus of the roots of an algebraic equation of the above type is shown to be identical with the singular lines of a certain fluid flow in a plane.

In the second chapter application is made to the study of the stability and guidance (by radar) of a missile, the trajectory of which deviates slightly from the vertical and lies in a vertical plane. The problem is reduced to the investigation of the stability of the characteristic equation of degree six of a certain differential system. Modifying the so-called "stabilizing and guiding coefficients" it is aimed at best stabilization with a short transition time and greatest flexibility in the guidance of the missile.

In the third and final chapter an example is given to illustrate the numerical calculations of the trajectories of the missiles. Author's approach is novel and of practical interest.

E. Leimanis, Canada

587. Iakubovich, V. A., The small parameter method for canonical systems with periodic coefficients, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **23**, 1, 17–43, 1959. (Pergamon Press, 122 E. 55th St., New York 22, N.Y.)

Author considers systems of the form $x_t = [C + \varepsilon B(\theta t, \varepsilon)]x$ where the matrix C is constant, the matrix B is analytic in ε and periodic with respect to θt in the interval $(0, 2\pi)$. His interesting paper is similar to investigations by L. Cesari [*Mem. Accad. Italia* (6) 11, 633–695 (1941)] and J. K. Hale [*Riv. Mat. Univ. Parma* **5**, 137–167, 1954], but his approach is different. Using the method of perturbation, author describes the computation of the coefficients of the corresponding expansion with respect to ε for the solution. Formulas are explicitly given for the approximation up to the order of ε^3. In particular the author deals with canonical systems and investigates the so-called case of "resonance" or "parametric instability." As an example, a system of two second-order equations which occurs frequently in the theory of plates is considered. After a suitable transformation the integral of this system is approximated for values of θ near the significant "combined" frequency $\omega_1 + \omega_2$, and the corresponding region of dynamic instability is determined.

R. Albrecht, Germany

588. Stiefel, E., Note on Jordan elimination, linear programming and Tchebycheff approximation (in English), *Numerische Mathematik* **2**, 1, 1–17, Jan. 1960.

Consider solution of an inconsistent set of linear equations

$$\eta_j = \sum_{k=1}^{m} a_{jk}x_j + c_j = 0, \quad j = 1, 2, \ldots n$$ so that the solution x_k minimizes $\zeta = \text{Max}\,|\eta_j|$. There are two methods of solution. (1) Minimizing methods start from a trial solution x_k and use an algorithm to diminish ζ at each step of the scheme. A routine is available which requires only a finite number of steps. This is called the Zuhovickii algorithm. (2) Theorems based on the classical results of DeLa Vallee-Poussin. Present author has developed an algorithm of this kind called the exchange method. Here author shows that the Zuhovickii algorithm and the exchange method are completely equivalent to the well-known simplex algorithm of G. B. Dantzig. Also these algorithms are dual programs in the sense of the terminology of linear programming.

Y. L. Luke, USA

589. Veidinger, L., On the numerical determination of the best approximations in the Chebyshev sense (in English), *Numerische Mathematik* **2**, 2, 99–105, Mar. 1960.

Author considers an elaborate algorithm for the determination of the polynomial of best approximation (the so-called second algorithm of Remes). The principle of this technique is similar to the exchange algorithm [see the preceding review]. Author proves certain results on rapidity of convergence of the Remes algorithm.

Y. L. Luke, USA

590. Biot, M. A., and Tolstoy, I., Canonical and Hamiltonian formalism applied to the Sturm-Liouville equation, *Quart. Appl. Math.* **18**, 2, 163–172, July 1960.

The paper is concerned with differential equations of the form

$$[(d/dz)(f dq/dz)] + gq = 0$$

where f and g are known functions and q is an unknown function of z. The analytical or numerical solution of this equation is facilitated by a transformation of the dependent variable. This is illustrated (assuming that $f = 1$ and $g \geqslant 0$) by the transformation

$$q = (2Q)^{1/2} \sin P$$

$$Q = Q_0 \exp \int_{z_0}^{z} (g - 1) \sin 2P\, dz$$

where P is the new dependent variable and Q_0 and z_0 are constants. The differential equation thus obtains the form

$$(dP/dz) + \cos^2 P + g \sin^2 P = 0$$

and can be solved by expanding $\tan P$ in powers of g. Generally it may be expected that P does not vary too rapidly with z, whereas q would be an oscillating function. In developing the general

theory of the relevant transformations, use is made of the canonical transformations of classical mechanics. While presenting the theory and some of its applications in detail the author does not work out any specific example to the extent that an explicit solution is given. R. Eisenschitz, England

591. Johnson, M. W., and Reissner, E., Parametric expansions for a class of boundary value problems of partial differential equations, *J. Soc. Indust. Appl. Math.* **8**, 2, 389–396, June 1960.

An expansion procedure is briefly described for a problem involving two independent variables and the domain in which a solution is wanted consists of a semi-infinite strip of well-defined width. For the purpose of comparison of the series expansion with an exact solution, paper considers the problem of a semi-infinite plate under the combined loading of a uniform tension in the strip-direction and a lateral load. The method proves to be effective for such a problem, as the obtained result agrees well in first approximation with the known exact solution.

H. C. Reggini, Argentina

592. Douglas, J., Jr., A numerical method for the solution of a parabolic system (in English), *Numerische Mathematik* **2**, 2, 91–98, Mar. 1960.

Author develops an implicit finite difference method for solution of a system of differential equations which arise in the description of two-phase flow of incompressible fluids in a multi-dimensional porous medium. The system is

$$\begin{aligned} \nabla\cdot(\alpha\nabla u) + \nabla\cdot(\beta\nabla v) &= 0 \\ \nabla\cdot(\beta\nabla u) + \nabla\cdot(\alpha\nabla v) &= \gamma\frac{\partial v}{\partial t} \end{aligned} \qquad [1]$$

where α, β and γ are functions of s, y and v. A backward difference approximation to [1] is used. Author assumes the heuristic view that lower-order terms in a differential operator do not affect the convergence or divergence of the difference analog of the differential operator. To study convergence, author replaces [1] by

$$\left.\begin{aligned} \alpha\nabla u + \beta\nabla v &= 0 \\ \beta\nabla u + \alpha\nabla v &= \gamma\frac{\partial v}{\partial t} \end{aligned}\right\} \qquad [2]$$

and shows that backward difference approximation does converge to the solution of [2]. The author also studies an alternating direction iteration procedure for the solution of [1].

Y. L. Luke, USA

593. Rose, M. E., A method for calculating solutions of parabolic equations with a free boundary, *Math. Comput.* **14**, 71, 249–256, July 1960.

The description of phenomena involving phase transitions leads to title equations with a free interior boundary which marks the interface separating the phases. For previous work on the subject see AMR **9** (1956), Rev. 3763; **11** (1958), Rev. 1365; **13** (1960), Revs. 2529–2530. See also W. Trench, "On an explicit method for the solution of a Stefan problem," *J. Soc. Indust. Appl. Math.* **7**, 184–204, 1959. Point of present paper is to suggest a computational approach where path of interface is not regarded as an explicitly imposed interior boundary condition. A numerical example is provided to illustrate the discussion.

Y. L. Luke, USA

594. Gol'denveizer, A. L., Asymptotic integration of linear partial differential equations with a small principal part, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **23**, 1, 44–74, 1959. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

This paper is a continuation and completion of two earlier works of the author [see AMR **9**(1956), Rev. 2876, and AMR **13**(1960), Rev. 3223] and the reader should be familiar with the results and notations given there. The investigations concern linear differential equations of the form $b\,N(\phi) + L(\phi) = 0$ where b is a small parameter which appears in the coefficient of the derivatives of highest order, while N and L are differential operators in two independent variables. Problems to be considered are the boundary-value problem for elliptic equations, Cauchy's problem for hyperbolic equations, and the problem to construct a particular integral of an equation of arbitrary type. It is assumed that the boundary values of the solution depend on a large parameter k, and represent rapidly oscillating functions. The nature of the solutions is investigated and various methods of constructing approximations to the solutions according to the relation between the parameters b and k are discussed. The paper is somewhat laborious to read.

R. Albrecht, Germany

595. Ikenberry, E., The evaluation of collision integrals, using Grad's representation of the distribution function (in English), *Arch. Rational Mech. Anal.* **3**, 2, 123–132, Apr. 1959.

By assuming the distribution function can be expanded in a uniformly convergent series of three-dimensional Hermite polynomials, author shows that all but two of the eight integrations needed to determine all collision integrals in the Maxwell-Enskog transport equation for spherically symmetric intermolecular force fields can be evaluated. He also shows that for rigid elastic spheres of diameter d all of the integrations can be effected and that for inverse power molecules all but one can be and this latter one can be effected numerically. Although these results follow logically from Grad's well-known 1949 paper on kinetic theory, and like it are highly mathematical, they will be of significance and use to all workers in the kinetic theory of gases.

R. E. Street, USA

596. Szczepinski, W., Statical analogy in the study of deviations in complex dimension nets (in English), *Bull. Acad. Polonaise Sci.* **7**, 6, 365–370, 1959.

Analogy between dimension nets and bar systems is demonstrated and applied. Changes of distance between two nodes and of angle between two directions are computed by studying the behavior of the analog bar system under the action of unit forces and moments. Standard deviations of these changes of dimensions can also be computed in function of the standard deviation of each component. Method is described as particularly suitable for analyzing deviations in spatial dimension nets.

F. Borges, Portugal

597. Dorn, W. S., Duality in quadratic programming, *Quart. Appl. Math.* **18**, 2, 155–162, July 1960.

The programming problem under consideration concerns the minimization of a quadratic expression in non-negative variables that are subject to a set of linear inequalities. A dual maximum problem is constructed, and the following theorem is established: if there exists a solution to one of the problems, there also exists a solution to the other, and the two extrema have a common value. Other quadratic programming problems are listed with their duals. In the most simple of these, the variables are not restricted in sign and the subsidiary conditions are equations rather than inequalities. The extremum principles of the theory of elastic trusses are discussed, because they illustrate this kind of dual problem. (A truss with wire diagonals that are unable to transmit compressive forces would provide a structural illustration of variables with sign restrictions, but all these structural examples suffer from the following weakness. In the theory of structures, the existence of dual variables, i.e., the bar forces and extensions linked by Hooke's law (and inequalities in case of wire members), is the basic fact from which the dual extremum formulations are derived. In programming theory, however, one is given one extremum problem and deduces the existence of the dual extremum problem.) W. Prager, USA

598. Gumbel, H., Waiting lines with heterogeneous servers, *Operat. Res.* **8,** 4, 504–511, July/Aug. 1960.

Author treats queuing problem where parallel processing stations have service times with exponential distributions. Steady-state probabilities are derived. Comparisons are made with results where all serving stations have same average and cases where the distributions are replaced by average values.

T. E. Caywood, USA

Computing Methods and Computers

(See also Revs. 585, 588, 589, 608, 619, 621, 622, 626, 790, 1143)

Book—599. Kuntzmann, J., Numerical methods, interpolation and derivatives [Méthodes numériques, interpolation-dérivées], Paris, Dunod, 1958, xvi + 252 pp. 3600 F.

Author presents a textbook on numerical interpolation. Theory is treated on an elementary level, but carefully and rather completely; for example a chapter is devoted to confluent cases. Remarkably, a whole chapter deals with interpolation in the complex plane or in several variables. Two final chapters treat, briefly, nonpolynomial approximation. Theoretically, the author's direct way of introducing the Thiele continued fraction is interesting, but since, in the meanwhile, new algorithms have been published which are shorter and simpler, it is to be expected that rational approximation will deserve increased practical attention in near future. We hope that a second edition can take this into account.

F. L. Bauer, Germany

600. Miller, J. C. P., Numerical quadrature over a rectangular domain in two or more dimensions. Part 1: Quadrature over a square, using up to sixteen equally spaced points; Part 2: Quadrature in several dimensions, using special points; Part 3: Quadrature of a harmonic integrand, *Math. Comput.* **14,** 69, 13–20, Jan. 1960; **14,** 70, 130–138, Apr. 1960; **14,** 71, 240–248, July 1960.

Nature of work is aptly described by titles. Numerical examples are supplied to illustrate the formulas. A very useful set of papers.

Y. L. Luke, USA

601. Householder, A. S., and Bauer, F. L., On certain methods for expanding the characteristic polynomial (in English), *Numerische Mathematik* **1,** 1, 29–37, Jan. 1959.

To solve algebraic eigenvalue problem $A_u = \lambda_u$ ($A = n \times n$ matrix, u = vector) via solution of algebraic equation $\det(A - \lambda I) = 0$, authors show mathematical equivalence of various indirect methods (direct evaluation of minors is practically useless) depending on sequence of vectors $v_k = Av_{k-1}$, v_1 = arbitrary e.g. $(1,0,0,\ldots,0)$ or matrix $v = [v_1, v_2, \ldots v_n]$. Polynomial equation equivalent to $\det(A - \lambda I) = 0$ is constructed using (1) linear dependence of (at most) $(n + 1)$ vectors v_k (Krylov), (2) factorization of v into plane rotations (Givens), (3) Jordan reduction of v (Danilevskii), (4) transformation into easily expandable form $\det(T - \lambda I) = 0$, using: $AB = BT$, $B = VQ$, Q = upper triangular, T = upper triangular plus one subdiagonal consisting of ones (Hessenberg), (5) transformation of A into T by orthogonal matrices (Householder).

Authors give fair number of references, but no examples and no assessment of usefulness.

M. L. Meyer, England

Book—602. Grabbe, E. M., Ramo, S., and Wooldridge, D. E., edited by, Handbook of automation, computation, and control, Volume 2: Computers and data processing, New York, John Wiley & Sons, Inc., 1959, xxiii + 833 pp. + index. $17.50.

Computers and Data Processing is Volume II in the Automation Handbook series edited by Grabbe, Ramo and Wooldridge. Following the pattern set by the first volume which treated control fundamentals, Volume II is directed to the problem solvers and technical management who are concerned with applied technology. The emphasis is on practical methods of applying theory and the text concerns itself principally with the design and application of digital and analog computers.

The collected set of chapters and text by forty one authors is welded together into a comprehensive handbook by the editors. Most of the contributors are working in industry and are close to a digital computer; hence the contributed articles are developed from actual experience. As in a true handbook, the material is arranged in such a way that one may review or study any chapter without recourse to previous chapters. Each chapter attempts to be a full treatment of its own subject matter and as such is self contained.

Computers and Data Processing begins with a chapter on computer terminology and symbols which serves as a set of fundamental definitions which are then common to all chapters. The text follows then with digital computer programming, and a number of chapters on the use of digital computers and data processors. These include the following: equipment description; data processing operations; design of business systems; miscellaneous applications to accounting, inventory control, scheduling, and scientific problems; and information retrieval. The text then develops fundamental concepts for the design of digital and analog computers. Included are fundamentals, design techniques, components, circuits, logic, reliability, and control elements. Input and output equipment are also discussed. The text concludes with a number of chapters covering unusual computer systems.

Unlike the pace set in Volume I, the text does not demand advanced training in mathematics or engineering. The mathematics required is set at an undergraduate level. However, some maturity or insight in the field of information handling would be helpful to the reader. The material in the text is presented in a clear and comprehensible manner, and the style enhances the subject matter.

The material in the chapter on programming and coding is unusually complete, covering fundamentals and principles. In addition, the instruction code is given for a variety of domestic computers and one foreign one, the Soviet Strela. The large number of order codes provided by the author appears unnecessary if the purpose is to illustrate the fundamental principles of coding. On the other hand, the author may have included these codes because of the large number of users of these equipments, and the desire to provide, in one place, the type of data provided by the equipment manufacturers in separate catalogs. Typical practicing engineers and problem solvers for whom the text is aimed will probably have little interest in the Soviet Strela and its order code. In general, the programming and coding section represents a large segment of the text and is written in a competent and professional manner.

The text is skimpy and hence disappointing with regard to business applications and the use of computers for decision making. These areas are not treated in any detail and the text is not properly balanced with regard to such data. This area of the text will probably be unsatisfactory to problem solvers, but perhaps the importance of the subject may dictate a separate volume.

At least half of the text is devoted to engineering and design features of digital and analog computers. This part of the work is developed clearly and as fully as required to bring the basic features of modern information-handling machines into sharp focus. Included are many technical chapters giving details and techniques not commonly found in such ready reference. Engineers will find this area of the text very worthwhile, and very significant.

Volume II of the Handbook is a worthy addition to the library of the practicing engineer and business man. It represents a major contribution to the literature on the subject of automation.

J. W. Fischbach, USA

603. Antel, T., Application of computers in the chemical industry, Part 1 (In German), *Regelungstech.* **8,** 7, 227–233, July 1960.

Book—604. Jackson, A. S., Analog computation, New York, McGraw-Hill Book Company, Inc., 1960, xiv + 652 pp. $13.50.

The technique of analog computation is used more and more in almost every area of engineering and scientific research. Thus there is need for a comprehensive text on this technique but one not requiring a specialized background in electronics. "Analog computation" meets this need almost completely. The formal prerequisites are calculus and differential equations for mathematics and some basic knowledge on electronics. Laplace transformation is applied throughout the text, but an introduction is given in chapter 1.

In this first chapter, the concept of analog computation is dealt with. Chapter 2 presents the general-purpose analog computer and gives some basic information about its components. The fundamental methods to choose amplitude and time-scale factors are treated in Chapter 3. The use of the computer to solve ordinary linear and nonlinear as well as partial differential equations is covered in Chapters 4, 5 and 8, respectively. Chapter 6 describes the use of the computer as a simulator. Algebraic matrix problems are the subject of Chapter 9. The application of analog computation in the field of operations research is covered in Chapter 10. In Chapter 11, some representative applications are discussed.

A very important chapter is no. 7 where the techniques of problem preparation, programming and checking of solutions are dealt with. Of particular interest for electrical engineers are Chapters 12 and 13, where the electronic analog computer is treated in detail. An introduction into the digital technique is given in Chapter 14, and the combined analog-digital computer and its special features are discussed.

The book is written in a clear and comprehensive language and gives an excellent introduction into almost all the different problems related with the use of analog computers. It will be extremely helpful not only to students but also to the experienced computer programmer. P. J. Profos, Switzerland

605. Levine, L., Analog setup solves polynomials, plots root locus automatically, *Control Engng.* **7,** 10, 125–126, Oct. 1960.

Analogies

(See also Revs. 596, 922)

606. Cary, H., and Thomas, R. E., Accelerated testing as a problem of modeling, Proc. 6th National Symposium on Reliability and Quality Control in Electronics, Jan. 11–13, 1960; New York, Institute of Radio Engineers, pp. 69–87.

Author defines "accelerated testing" as a means of foreseeing the reliability of equipment and suggests use of models built according to this principle. Acceleration is obtained through the increase of stresses. (Reviewer emphasizes the fact that this model practice can work only if the laws relating failure rate to stress and time are known by application of the laws of physics or guessed by some extrapolation.) Further assumptions are related to mathematical probability (time-repetition of failures). An example of application is given in the case of a "hypothetical" turboprop control system. J. M. Loeb, France

607. Thorn, R. P., A practical guide to the mobility method: Part 1, Basic concepts and definitions; Part 2, Mechanical-network analysis, *Mach. Design* **31,** 25, 144–157, Dec. 10, 1959; **31,** 26, 104–111, Dec. 24, 1959.

Mobility is complex ratio of velocity to force, originally called mechanical admittance. In purely mechanical systems, mobility-element diagram is topologically similar to idealization of mechanical elements. Author describes process of making idealized mechanical sketch and equivalent mobility-element diagram, and how the network equations are solved. Examples worked out have no damping. Users should have knowledge of electrical circuit theory and manipulation of complex numbers. Paper is largely tutorial. V. Salmon, USA

608. Brignac, W. J., and Schwendler, R. G., Aircraft structural analysis on an analog computer, *Proc. Amer. Soc. Civ. Engrs.* **86,** EM 3 (*J. Engng. Mech. Div.*), 41–63, June 1960.

Paper briefly reviews pertinent analogic relations and discusses some applications of a direct analog structural computer which has been previously developed and described by others and has been widely used in this country during the past eight years or so.

J. E. Goldberg, USA

Kinematics, Rigid Dynamics and Oscillations

(See also Revs. 726, 728, 800, 907)

Book—609. Faires, V. M., Kinematics, New York, McGraw-Hill Book Co., Inc., 1959, xiii + 468 pp. $8.50.

According to the preface, the aim of author, who is professor of mechanical engineering, United States Naval Postgraduate School, is to cover those topics on the science of motion that are of most general interest to engineers in a book useful to teachers and students.

The matter is exposed in a succession of 15 chapters, with a combination of graphical and mathematical methods illustrated by a great many examples. In chapter 1, entitled "Equation of motion," reader will find, after the definition of kinematic chain and mechanism, the equations determining linear and angular motion, speed and velocity, acceleration, and the derivative of acceleration with respect of time (called jerk or pulse), this being of significance in the design of cams. Those fundamental notions are applied to different kinds of motion, constant velocity and acceleration, harmonic, slide crank mechanism, etc.

Methods for obtaining the motion diagrams by graphical derivation and integration are given. Tangential and normal acceleration are considered in curvilinear motion and applied in examples.

Chapter 2 is devoted to cams and especially to disk or plate cams. The general plan of graphical solutions for those mechanisms is exposed and applied to different motions, with radial and flat-face followers; the motion equations are written in each case. These studies give opportunity to define pressure angle, to show the influence on it of speed and basic circle, with the necessity of limiting the maximum value of pressure angle. The consequences of theoretical infinite jerk are put in evidence by means of acceleration records—given by tests for parabolic, harmonic and cycloidal motion—with computed accelerations. The study of special motion of oscillating and secondary followers, of special forms of cams, positive motion cams, cylindrical cams, and so on, completes this chapter.

The graphical determination of velocities in mechanisms is examined in three different ways in the chapters 3, 4 and 5. The centromethod (author means the instantaneous center of rotation) is used in chapter 3; primary centros are first located, the unknown centros are then determined by application of Kennedy's theorem and the velocities are finally found by using the properties of the velocities in rotating bodies; some usual mechanisms are considered at the end of this chapter and the centrode (path of the centro) is indicated.

The method of relative velocities, using the well-known equation between the two velocities, is exposed in chapter 4; the velocity polygon method is applied to several cases. The method of components, treated in chapter 5, is based on the fact that the distance between two particular points of a rigid body remains constant, hence given a straight line in a rigid body the orthogonal

projections on this line of the velocities of the several points of this line are equal.

In chapter 6 the relative acceleration equation for two points of a rigid body is developed, leading to the graphical location of the center of acceleration, while in chapter 7, the existence and the value of Coriolis acceleration are demonstrated.

The polygon construction deduced from the foregoing equations is applied to several mechanisms among which the reader will find the cams. The "Miscellaneous motion problems" treated in chapter 8 concern methods of drawing velocity and acceleration diagrams; construction for the slider-crank mechanism are specially considered.

The numerous questions relating to the kinematics of gears are exposed in the four chapters 9, 10, 11 and 12. In chapter 9, entitled "Spur gears," a general view on spurgearing will be found: nomenclature, fundamental property of normals which characterize conjugate profiles and which is satisfied for involute curve; properties of involute gearing; interchangeability, interference, field of action, minimum number of teeth, means of reducing interference; involutive rack and internal gears, sliding velocity, methods of gearcutting, cycloidal system, comparison between involute and cycloidal gearing. Chapter 10, entitled "Noninterchangeable tooth profiles," is an introduction to the methods used in practice in order to obtain better kinematic action of gears. The basic mathematical relations of involumetry are established and from them are deduced some consequences of modification of pressure angle and tooth thickness when displacing the cutter in gear manufacturing.

As the title "Helical, bevel and wormgearing" indicates, chapter 11 covers briefly those types of gears. Reader will find for helical gears, constitution, relations between circular and normal pitch and between pressure angles, advantages of helical gearing on spurgearing; use of virtual number of teeth, herringbone gears, crossed helical gears (velocity ratio, sliding velocity). For bevel gears are treated: nomenclature, velocity ratio, tooth profile determination (similar to the Tredgold method described in the appendix), the Gleason system of straight bevels, spiral bevels and hypoid gears. Wormgearing is briefly indicated at the end of this chapter.

Chapter 12 deals with "gear trains" including planetary trains. The train value is defined and the means for realizing a train with given value are discussed, taking in account the limiting values of the gear teeth. The general equation between the velocities in any planetary gear train is clearly exposed although reviewer prefers the use of the Willis rule. Application to reverted planetary trains, to bevel-gear differential for automobile and to automatic transmission closes this chapter.

Chapter 13 is devoted to "flexible connections and friction wheels." The kinematics of the devices are simple. For flat belts attention is drawn to the law of belting which must be observed if the belt is not to run off the pulley and on the length calculation of open and crossed belts. Indications will be found on V belts, roller chains, silent chains, friction drives leading to variable speed drive, for which examples are produced and hoisting tackles comprising differential hoist.

The synthesis of mechanisms is treated in chapter 14. Author remarks that synthesis approach to mechanisms has already been shown in the previous chapter, for instance in cams, but in order to better introduce the question, he considers noncircular rolling curves and establishes the mathematical relations between radii and angles of the two curves. These relations are then used to develop the procedure for designing rolling curves when, for instance, a velocity diagram is imposed. Examples are treated among which it is shown that a problem can be resolved by a linkage.

This leads to the synthesis of bar linkages. It is shown that if an infinite number of quadri-chains can resolve the problem of a body that must occupy two positions, only one quadri-chain is able to resolve the case when the body must occupy three positions.

From the methods indicated for designing bar linkages, the Atlas method (the useful atlas prepared by Hrones and Nelson) and a method called "overlay method" adapted to the double-slider one-bar mechanism, the four-bar mechanism and the slider-crank mechanism are retained. An example is developed for the first two mechanisms.

"Miscellaneous devices" are the subject of chapter 15. They include ratchet devices and universal joints for which the basic relation between the angles described is given.

In an Appendix reader will find some practical information: conversion table for degrees to radians, the dimensions of basic racks for gear-tooth system, drawing involute and cycloid curves and also the Tredgold method for bevel gears; some useful mathematical relations. It must be noted that after each chapter a very large number of problems, mathematical and graphical, are proposed to the reader. The book is written with long explanations that facilitate the understanding; the print and the figures are very clear. Author has realized the aim expressed in the preface: with this book "teacher will be able to accomplish more and the student will learn more in greater depth."

D. De Meulemeester, Belgium

610. Bottema, O., The pole of inertia of a Cartesian slider (in German), *Öst. Ing.-Arch.* **13**, 2, 103–105, 1959.

The pole of inertia of a plane system is the point through which the line of action of the resultant force passes. The location of the point is independent of velocity and acceleration. The system considered consists of a circle (disk) rolling inside a larger circle. It is shown that the locus of the pole of inertia is a circle in the plane of the moving body and an ellipse in the fixed or reference Cartesian system. The relationship between the fixed locus of the pole of inertia and the locus of the center of gravity of the rolling disk is derived. D. Kececioglu, USA

611. Grindei, I., On corresponding dynamical systems (in Roumanian), *Studii Si Cercetari Stint. Matematica* **9**, 2, 189–197, 1958.

Paper finds the systems corresponding in the sense given by Painlevé to a dynamical system with two degrees of freedom and with forces differing from zero. For the correspondence with the conservation of geodesics, author uses the conditions established by T. Levi-Civita, and for the correspondence which does not conserve the geodesics the conditions established by J. E. Wright. These conditions are restated in this paper in a simpler manner.

T. Hacker, Roumania

612. Broxmeyer, C., Foucault pendulum effect in a Schuler-tuned system, *J. Aero/Space Sci.* **27**, 5, 343–347, May 1960.

Three-axis analysis of an undamped, Schuler-tuned, inertial navigation system, carried by a vehicle moving near the Earth's surface, leads to a set of six simultaneous linear differential equations of the first order. Solution of the sixth-degree characteristic equation of this set shows that the system errors oscillate with the eighty-four minute period predictable from single-axis analysis and that, in addition, the errors exhibit beats with a period which varies with latitude and velocity. It is shown that this behavior has an analog in the behavior of a Foucault pendulum.

From author's summary by L. A. Gould, USA

613. Bauersfeld, W., The laws of motion of a spatial compass (in German), *Ing.-Arch.* **27**, 6, 365–371, 1960.

The behavior of the Anschütz-Schuler gyroscopic compass is studied in detail. It is proved that the compass is insensitive to acceleration, that one of its axes keeps to the vertical direction irrespective of any movement of the vehicle, etc. A warning is also given: oscillations, if accidentally excited, would be troublesome, because of their very long period. G. Capriz, England

614. Shlyakhtin, A. V., and Bortkevich, N. I., Determination of forced vibrations of systems with nonlinear restoring forces (in

Russian), *Trudi Inst. Mashinoved., Akad. Nauk SSSR* **19**, 74, 58-67, 1959.

The vibrations caused by harmonic forcing terms are calculated for a system with nonlinear restoring forces. The nonlinearity is approximated piecewise by straight lines. The solutions for each of the linear intervals can be found in a well-known manner. In demanding continuity at the boundary points of the intervals, the calculation leads to a transcendental system of algebraic equations. Choosing a suitable set of new unknowns the equations sometimes can be solved. The method is applicable for strong deviations of the characteristics from the linear case. Some examples are calculated.

K. Magnus, Germany

615. Melyakhovetskii, A. S., One hypothesis of internal resistance to vibrations of elastic systems (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **26**, 285-286, 1958.

This paper represents the critique on Sorokin's book "Method for taking into consideration nonelastic resistances in the investigation of structure vibrations" [Gos. Izd. Str. Lit., 1951] regarding the general expression for the internal resistance force $F = [1 + (i\psi/2\pi)]S$, where S is elastic force and ψ the damping coefficient. The author shows that this general expression is not valid because the differential equation of vibration composed by means of above formula has unbounded solutions. This assertion is confirmed by one simple example, namely, the case of the free vibrations of a system with one degree of freedom.

D. Raskovic, Yugoslavia

Instrumentation and Automatic Control

(See also Revs. 602, 612, 842, 1092, 1093, 1128)

Book—616. Industrial telemechanics [Prom'shlennaya telemekhanika], Moskva, Izdatel'stvo Akademii Nauk SSSR, 1960, 285 pp. 18 r 55 k.

This volume on telemechanics comprises articles by various Soviet authorities in the field. It was put out under the auspices of the Institute of Automatics and Telemechanics in Moscow and is edited by M. A. Gavrilov. The book is largely devoted to encoding and decoding schemes for telemetering signals transmitted for purposes of information and control. The problems treated arise in the production of gas and oil, electrical power, in the rail transportation of goods, and elsewhere. Relays with and without contacts are discussed, involving mechanical, magnetic vacuum tube and solid-state devices. Means for using impulses and other signals for triggering actions are covered in some detail. Matrices are employed in the study of networks for the transmission of binary information.

In the opinion of the reviewer the volume presents a comprehensive picture of the state of telemetering in current Soviet industry.

R. Oldenburger, USA

617. Nishimura, T., Operational analysis of finite-pulsed sampled-data systems, AFOSR TN 60-510 (Univ. California, Electronics Res. Lab., Dept. Electrical Engng.), 37 pp., May 1960.

The theory of the operational analysis of the finite-pulse-width system is developed in this report. The closed-form expression of the response from such a system is described by means of several well-known operators such as the z-transform, the modified z-transform and the simple form of the p-transform.

Finding the incremental responses and their superposition is the basic principle of the theory and it is also applied to two-sampler systems as well as multi-rate sampling systems.

From author's summary

618. Stear, E. B., and Leondes, C. T., Extended synthesis techniques for multipole sampled-data control systems, AFOSR TN 59-1223 (Univ. Calif., Dept. of Engng.), 12 pp., Oct. 1959.

619. Aoki, M., Dynamic programming and numerical experimentation as applied to adaptive control systems, Univ. Calif., Dept. Engng. Rep. no. 60-16, 215 pp., Feb. 1960.

This report forms a part of a continuing program in digital technology at the University of California, Los Angeles. It is in essence the content of the author's doctoral dissertation in engineering. Author presents formulations of certain control processes as variational problems in the time domain. Ultimate interest is centered on a class of adaptive control systems. Author selects the time rather than the transform domain in order to deal directly with nonlinear systems and criteria for optimization of the control function. The attack on the mathematical structure of solutions is essentially a numerical simulation of the analytic formulation. Author refers to this approach as experimental mathematics. Solution structure is hypothesized and tested numerically. Effects of parameter changes and control criteria are developed by numerical computation. Comparisons with corresponding analytic approximations are made.

Author develops a dynamic programming description of the control problem. Such formulation views the control process as a series of point transformations in phase space applied to the state vectors of the control system. Different types of transformations correspond to various criteria of control performance. Concepts from statistical decision theory and game theory are also introduced to deal with significant aspects of adaptive processes.

Chapter I reviews time representation of physical systems. Interest is directed toward time transformations which are a function of the state vector as well as the time. Explicit and implicit criteria of performance are discussed. The role of point and integral constraints are treated in light of dynamic programming techniques.

Chapters II and III present a dynamic programming formulation of deterministic and discrete stochastic control processes. The latter are assumed to be of the Markov type. Chapter IV discusses use of Lagrange multipliers for incorporating integral constraints into control performance criteria. Chapters V and VI address themselves to adaptive control problems. These are characterized by systems having random inputs with unknown probability distributions. Two general problems are considered. The first case concerns a system subject to random inputs having finite possible states. In the second case, the probability distribution function governing the random variable of the control system is a member of a class of distribution functions characterized by a parameter set.

Chapter VII outlines two computational procedures for the solution of recurrence relationships. Difficulties arising in computations associated with functional equations of high dimension are discussed. Various procedures are suggested for reducing the numerical burden. The remaining three chapters present numerical examples illustrating the use of techniques covered by Chapter VII.

While this report may be a disappointment to those seeking cookbook answers to complicated control problems, reviewer believes author has provided an excellent conceptual framework and a sound basis for continuing progress in control system synthesis and analysis. Methods suggested by the author have real merit in certain cases and possible future lines of investigation are clearly indicated. Control engineers should find this report both stimulating and rewarding.

R. B. Grant, USA

620. Gibson, J. E., Making sense out of the adaptive principle: Part 1, *Control Engng.* **7**, 8, 113-119, Aug. 1960.

621. Naumov, B. N., Approximate determination of transients in nonlinear servomechanisms (in French), *Automatisme* **5**, 4, 133-139, Apr. 1960.

Servo loops of arbitrary complexity but containing just one nonlinear element E are considered. It is shown that the variable input to E satisfies an integral equation, the integral being a convolution of the output of E and the response to an impulse of the remainder of the loop. The equation is solved by a finite difference method in which the integral is replaced by a sum of values of the integrand at discrete points. C. M. Ablow, USA

622. Challe, J., Application of finite difference methods for the automatic control of the temperature of systems with large thermal inertia (in French), *Automatisme* **5**, 4, 147–153, Apr. 1960.

It is argued that in a servomechanism of great inertia an on-off regulator linear in error approximates the actual regulator. The regulation due to the actual error is approximated over short time intervals by regulation due to constant errors. The resulting equations of response to step errors are readily solved analytically so that parameter adjustments for stability or optimization can be made. This paper cannot be understood independently of its predecessor [AMR **13**(1960), Rev. 573].

C. M. Ablow, USA

623. Klubnikin, P.F., Unified twin-drive servosystems, *Automation and Remote Control* **20**, 2, 154–168, Jan. 1960. (Translation of *Avtomatika i Telemekanika, USSR* **20**, 2, 161–176, Feb. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

A unified twin-drive servomechanism consists of two loops, of which the inner takes its feedback from its own output, while the outer takes its feedback from the sum of its own output and that of the inner loop, the two being added in a mechanical differential. In the case of a position servo, the inner loop can be of the velocity type, in which case it is fed with a derivative of the input signal, or a position type (in this case, for some unexplained reason, its feedback is shown as an integrated velocity signal). The outer loop is shown with a velocity feedback taken from its own output. The system is also shown applied to velocity servos, and to a velocity/position servo.

It is shown that servos with zero velocity and even zero acceleration errors can be quite conveniently obtained from this kind of build-up, and it is also claimed that the bandwith is superior to that of plain servos of comparable refinement. Experimental response curves are given to illustrate the performance.

It is claimed that good performance is obtained even under conditions involving saturation, and perhaps (though this is not explicitly stated) this is the chief advantage over orthodox servos having the same transfer function. Perhaps also (again this is not explicit) the transfer functions obtained are not so easy to realize by orthodox methods, i.e. networks.

A similar though less far-reaching approach [J. R. Moor, "Combination open-cycle, closed-cycle systems," *Proc. IRE* **39**, no. 11, 1951] is cited from western sources.

Reviewer feels that this development might repay close attention. R. Hadekel, England

624. Nakada, T., Feedback control increases the accuracy of machine tools, *Bull. Tokyo Inst. Technol.* (*B*) no. 2, 57–99, 1960. (Special Rep. Res. Lab. Precision Machinery and Electronics (P.M.E.), no. 5)

First, in the light of feedback control theory, the finishing accuracy of a hydraulic duplicating lathe is discussed analytically. The influence of the disturbance caused by the inaccurate guide way of the bed on the finishing accuracy is diminished by the nature of feedback control.

Second, the development of the feedback control technique to increase the finishing accuracy in a screw cutting lathe and a gear hobbing machine is described. Finally, the effectiveness of the feedback error compensation is evaluated by actual test on a special gear hobbing machine built by the author for experimental purposes.

From author's summary by G.D.S. MacLellan, Scotland

625. Baker, R. A., A look at generating station automation, *Combustion* **32**, 3, 36–40, Sept. 1960.

626. Adams, J. J., An analog study of an airborne automatic landing-approach system, NASA TN D-105, 57 pp., Dec. 1959.

An airborne automatic landing approach system is proposed, requiring only a simple radar target on the ground, which would be a worthwhile advantage in providing bad-weather facilities for an airfield. The tracking radar in the airplane, together with attitude gyros measuring pitch, roll, and direction angles of the airplane, furnishes signals by which rudder, aileron, elevator, and throttle are operated to control the airplane.

The results of an analog study of such a system are presented, assuming a swept-wing fighter airplane, simulated by six-degree-of-freedom equations with linear aerodynamic coefficients. This study investigated the maximum gains which could be used on the error signals; it also analyzed the effect of disturbances such as random gusts, steady cross winds, flap deflection, and radar noise. Results were indicated as satisfactory except for an instability when subjected to downward winds at short range. This was apparently remedied by introducing a first-order filter on the Euler elevation angle term in the elevator command equation.

R. L. Sutherland, USA

627. Bock, C. D., and Mundo, C. J., Guidance techniques for interplanetary travel, *ARS J.* **29**, 12, 931–940, Dec. 1959.

The problem of guidance to near planets with low specific impulse engines is examined. Trajectories to which the vehicle must adhere in order to minimize fuel consumption are treated in order to evolve which measurable parameters are suited for guidance. Criteria are established for the judging of suitability of these measurement parameters. Various possible measurement techniques are catalogued into active electromagnetic techniques, passive electromagnetic techniques and inertial techniques. The merits of the individual methods and the classes are studied.

From authors' summary by T. Gullstrand, Sweden

628. White, J. S., Investigation of the errors of an inertial guidance system during satellite re-entry, NASA TN D-322, 42 pp., Aug. 1960.

During the reentry phase of a manned satellite, inertial guidance equipment may be required for continuous onboard indication of position. Such equipment, however, has an inherent instability in the computation of altitude. This analytical study of an inertial guidance system shows that for reasonable values of initial-condition errors and equipment biases, the resultant position indication errors will not become excessive unless the reentry maneuver time is greater than 45 minutes to an hour. Further, the position indication error caused by accelerometer uncertainties can be reduced by leaving the accelerometers off until their output becomes significantly greater than their uncertainty.

From author's summary

Tables, Charts, Dictionaries, etc.

(See also Revs. 680, 1034)

629. Levit, D. E., Nomographic solution of equations of the fourth and fifth degree (in Russian), *Inzhener. Sbornik Akad. Nauk SSSR* **27**, 203–206, 1960.

Equations are written

$$v^4 + b_1 v^3 + b_2 v^2 + b_3 v + 1 = 0,$$

$$v^3 + c_1 v^2 + c_2 v^2 + c_3 v + 1 = 0.$$

Charts are self-explanatory. A. S. Householder, USA

630. Glass, I. I., Heuckroth, L. E., and Molder, S., On the one-dimensional overtaking of a shock wave by a rarefaction wave, Univ. Toronto, Inst. Aerophys. TN 30, 30 pp., July 1959.

Authors outline the phenomenon qualitatively using the (p, u) and (x, t)-planes. Reviewer found this concise and helpful.

The governing equations (algebraic) for a perfect inviscid gas are solved numerically on a high-speed digital computing machine in terms of initial pressure ratios across the shock and rarefaction waves in the range of 1 to 1000 and for physical specific heat ratios in the range of 1 to 5/3. Results are presented in graphical form and make possible the determination of final waves and states in terms of given initial conditions.

Reviewer believes the discussion is of sufficient detail to understand computed results and serves to clarify this phenomenon which is discussed in many standard references. Several appendices are included in which governing equations are derived and special cases are considered, i.e., when $\gamma = 5/3$ and unity. The graphical results can be of engineering interest for any process involving interaction of shock and rarefaction waves. Reviewer knows of no other source for such detailed computations of this phenomenon. A. Kovitz, USA

Elasticity

(See also Revs. 587, 594, 668, 672, 675, 677, 678, 680, 683, 694, 695, 696, 697, 704, 727, 787, 797, 808)

631. Bramble, J. H., and Payne, L. E., On some new continuation formulas and uniqueness theorems in the theory of elasticity, AFOSR TN 60-723 (Univ. Maryland, Inst. Fluid Dynamics and Appl. Math. TN BN-213), 28 pp., July 1960.

New continuation formulas are explicitly derived for equations of elasticity. It is assumed that the displacement vector satisfied the field equations of elasticity in a region D, a portion Q of whose surface is spherical, and (1) the normal component of traction and the normal displacement vanish on Q, or (2) the tangential tractions and tangential displacements vanish on Q. Can the displacement vector be continued across Q as a solution of the equations of elasticity? The answer is yes for (2) and no for (1) unless the normal component of the rotation vector is also zero on Q, in which case the answer becomes yes.

Uniqueness theorems are also considered in two cases: (1) the components of the displacement vector satisify the equations of elasticity on the interior (or exterior) of a sphere. On the surface, boundary values of the normal component of surface traction and the normal displacement are prescribed; (2) the same as (1) except that the tangential components of the surface traction and the tangential components of the displacement are prescribed. In (1) if conditions are imposed in the region exterior to the sphere (with appropriate conditions at infinity), then the solution is unique. In the case of the interior problem a remarkable result is obtained, namely, if Poisson's ratio $= (N - 2)/(2N - 1)$ where $N =$ positive integer, then the boundary-value problem does not have a unique solution, but is unique for all other values of Poisson's ratio. A corresponding analysis is carried out for (2). When the tangential components of surface traction and the tangential components of displacement are prescribed over a complete spherical surface the solution will not exist and a compatibility condition is derived to ensure existence. The problems treated by the authors are acknowledged to be "unnatural" in a physical sense, but it is asserted that the results are intrinsically interesting and are potentially valuable in more general problems.

F. V. Pohle, USA

632. Segawa, W., Measures of finite strain and stress-strain relations, *J. Phys. Soc. Japan* **15,** 3, 518-522, Mar. 1960.

Stress-strain relations for large elastic deformations are expressed in a variety of equivalent forms which do not appear to be new. A. E. Green, England

633. Bondar, V. D., Certain accurate solutions of the compatibility equations for the deformation tensor components in the case of a simple load, *Soviet Phys.-Doklady* **5,** 1, 71-73, July/Aug. 1960. (Translation of *Dokladi Akad. Nauk SSSR (N.S.)* **130,** 6, 1218-1219, Jan./Feb. 1960 by Amer. Inst. Phys., Inc., New York, N. Y.)

In a work of L. I. Sedov it was shown that, to a simple load, there corresponds a certain special type of deformation, and the compatibility equations were found which must be satisfied by the components of the finite deformation tensor ϵ_{ij} for a simple load. Author considers the compatibility equations in a more detailed way, and obtains two accurate solutions of these equations.

From author's summary

634. Rudiger, D., A generalization of the principle of minimum potential energy of an elastic body (in German), *Ing.-Arch.* **27,** 6, 421-428, 1960.

In the general boundary-value problem of elastostatics the kinematic boundary conditions concern surface displacements and the static boundary conditions involve surface tractions. The principle of minimum potential energy singles out the displacement field of the solution from all displacement fields that possess the necessary continuity and differentiability properties and satisfy the kinematic boundary conditions. An analogous statement can be made concerning the principle of minimum complementary energy, which characterizes the stress field of the solution. In both cases, the solution can be shown to furnish an absolute minimum. E. Reissner [Proc. Symposium on the Calculus of Variations and its Applications, Chicago, 1956; Amer. Math. Soc., Providence, 1957] has established a variational principle that characterizes both the stress and the displacement fields of the solution, furnishing the differential equations of elastostatics as Euler equations and the boundary conditions as natural boundary conditions.

The variational principle of the present problem takes an intermediate place between the classical extremum principles and the variational principle of Reissner. It singles out the displacement field of the solution from all displacement fields with the necessary continuity and differentiability properties, regardless of whether they fulfil the kinematic boundary conditions. (Unfortunately, the principle is stated in a form that does not clearly exhibit its structural relation to the principle of minimum potential energy. It can be cast into an alternative form, in which the minimand is obtained from the potential energy by adding a surface integral extended over that part of the boundary where surface displacements are prescribed. The integrand is the scalar product of the surface traction computed by Hooke's law from the considered displacement field with difference between the given and the considered surface displacement.) The application of the elastostatic boundary-value problem is discussed, Saint-Venant's torsion problem being treated as an example. W. Prager, USA

635. Vodicka, V., An infinite elastic medium loaded by general body forces (in German), *ZAMM* **39,** 1/2, 2-8, Jan./Feb. 1959.

Stress tensor is determined by solving a system of three equilibrium and three compatibility equations with the aid of three-dimensional Fourier transformations. The special case of a single load appears here as a very simple problem.

R. Schmidt, USA

636. Szelagowski, F., A semi-infinite plate under the action of internal load (in English), *Bull. Acad. Polonaise Sci.* (IV) **7**, 7/8, 431–436, 1959.

Author solves the plane elastostatic problem of a half-plane loaded by opposing collinear concentrated internal forces acting parallel to the edge of the half-space. Solution is obtained by complex variable methods making use of an earlier solution for similar loading in a fully infinite plane. Present solution can be extended by superposition to more complex internal loadings or by mapping to other shaped regions. W. P. Graebel, USA

637. Kurshin, L. M., Mixed plane boundary value problem of the theory of elasticity for a quadrant, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **23**, 5, 1403–1408, 1959. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

The Muskhelishvili complex variable approach is used to solve the plane problem of the 90-degree infinite wedge with clamped-free edge conditions and a concentrated force at any point in the interior. The problem is reduced to one of determining the shear stress distribution at the clamped edge; an explicit series expression for the shear is obtained. It is shown that an infinite stress exists at the corner, but no numerical results are presented.

R. A. Eubanks, USA

638. Eder, L., Contribution to solving the differential equations of the elastomechanics of three-dimensional space for infinitesimal displacements in Cartesian coordinates (in German), *Forsch. Geb. Ing.-Wes.* **25**, 4, 101–105, 1959.

The field of the elastomechanics of three-dimensional space is governed by 15 partial differential equations for the normal stresses, the strains, the angular displacements and the absolute translations in direction of the three axes of a Cartesian coordinate system. Through suitable combination of these determinantal equations it was possible to establish a group of partial differential equations of fourth order for the elastodynamic as well as for the elastostatic case, when each of the individual equations is valid for one of the desired 15 quantities. In case of diminishing volume forces all equations of a group assume identical form. A general solution of the thus obtained two basic differential equations of elastostatics and elastodynamics cannot be given, while a multitude of particular solutions can be found. The difficulty in solving definite problems consists of picking from the multitude of particular solutions those which satisfy the boundary and initial conditions. From author's summary by F. W. Wendt, USA

639. Atsumi, A., Stress concentrations in a strip under tension and containing two infinite parallel rows of holes, *Technol. Rep. Tohoku Univ.* **23**, 1, 31–46, 1958.

Author uses solutions for repeated concentrated forces applied at the hole centers to generate four sequences of biharmonic functions. Each member of each sequence has singularities at the hole centers and is traction-free at the strip edges. The required solution is constructed by adding the uniform tension field to an infinite series constructed from the sequences, determining the series coefficients to clear the hole boundaries of tractions. The resulting infinite algebraic system is solved by perturbation. Numerical results are given. R. A. Eubanks, USA

640. Kogan, B. I., Axially symmetric problem of the theory of elasticity for a multilayered half-space (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 6, 111–113, June 1958.

A general solution is given of axisymmetrical problems, for a multilayer extended medium, of theory of elasticity by use of the stress functions of the Girkmann-Shapiro type.

R. M. Evan-Iwanowski, USA

641. Reiner, M., Research on second-order effects in infinitesimal elasticity of metals, Tech. Res. Dev. Foundation, Ltd., Haifa, 47 pp., Apr. 1958/Dec. 1959.

This paper reports on experiments made in twisting wires of steel, phosphor bronze and nickel. It is shown that there are changes of length of the second order which are nearly all elongations. One case of shortening was also observed. The conclusion is drawn that the complete four-parameter equation

$$s_{ij} = (\lambda \mathrm{I} + \delta \mathrm{II})\,\delta_{ij} + 2\mu\,\varepsilon_{ij} + 4\mu\,\varepsilon_{i\alpha}\,\varepsilon_{\alpha j}$$

must be used for an adequate representation of second-order phenomena in infinitesimal elasticity.

From author's summary

642. Lyubimov, V. M., Approximate solution of problems for certain particular cases of loading on elastic ring sectors (in Russian), *Inzhener. Sbornik Akad. Nauk SSSR* **26**, 137–147, 1958.

Stress tensor is represented as a sum of a principal and a correcting tensor. Principal tensor satisfies the equilibrium equations and prescribed boundary conditions. Correcting tensor satisfies the equilibrium equations, zero boundary conditions, and contains a sufficient number of parameters to be determined from the condition of minimum energy.

Paper is devoted to the construction of principal tensors for tangential and normal tractions. R. Schmidt, USA

643. Pohle, F. V., Lardner, T. J., and French, F. W., Temperature distribution and thermal stresses in structures with contact resistances, AFOSR TN 60-504 (Polyt. Inst. Brooklyn, Dept. Aero. Engng. Appl. Mech., PIBAL Rep. no. 557), 28 pp., May 1960.

The temperature distribution in a built-up structure in the form of an I-section is investigated for the case of a contact resistance at the junction of the cover plates and web. The equations are solved by the Laplace transformation technique for the case of aerodynamic heating; however the main emphasis is on the case of constant rate of heating. Comparisons are made with previous analyses which neglected the contact resistance. Graphs of temperatures and stresses show a comparison of theory and experiment for the case of constant flux of heat to the cover plates.

M. Holt, USA

644. Cowper, G. R., Thermal stressing due to an arbitrary heat source in a circular cut-out, Nat. Res. Counc., Canada MS 101, 22 pp., Mar. 1960.

Author reviews the known solution for a circular disk with a concentric hole, subject to an arbitrary temperature distribution on the circular boundaries. Stresses and displacements are given and plotted in graphic form. An extension to an infinite plate is made by expanding the outer radius indefinitely. Two numerical examples are worked out.

Reviewer considers the approximate solution proposed by author for an infinite plate to be valid only at the vicinity of the hole. At large distance, a valid solution could be worked out by shrinking indefinitely the size of the hole. D. H. Cheng, USA

645. Parkes, E. W., Heat conduction and thermal stresses in a solid having unequal specific heats, AFOSR TN 60-320 (Stanford Univ., Dept. Aero. Engng. no. 90), 23 pp., Feb. 1960.

It is usual in thermoelastic analyses to separate the heat conduction and stressing problems. This division can only be justified if the specific heat at zero stress for the material is closely equal to that at zero strain. For some materials at present under consideration for missile construction, the ratio of specific heats may depart from unity by 25%. Author investigates the transient temperature distribution and thermal stresses in a solid subjected to one-dimensional heat flow and various kinds of stress-inducing restraints, when the specific heats are unequal. Allowance is made for the stress terms in the heat conduction equation (which are ignored when the analysis is divided) and for the variation of

specific heat with temperature. It is concluded that the errors introduced by the conventional approach, although not entirely negligible, are not such as to justify the labor involved in the more correct analysis.

From author's summary by H. Faught, USA

646. Olesiak, Z., and Sneddon, I. N., The distribution of thermal stress in an infinite elastic solid containing a penny-shaped crack (in English), *Arch. Rational Mech. Anal.* **4**, 3, 238–254, Jan. 1960.

In this highly mathematical paper, the problem is attacked by methods previously used on similar tasks by Sneddon [e.g. Sneddon I. N., The distribution of stress in the neighbourhood of a crack in an elastic solid, *Proc. Roy. Soc. Lond.* (*A*) **187**(1946)]. The partial differential equations of equilibrium and temperature distribution are replaced by ordinary differential equations by the use of Hankel transforms. The equations are first solved for a semi-infinite solid with axially symmetrical boundary conditions; next a general solution is derived for a prescribed flux of heat across the surfaces of a penny-shaped crack. Special cases treated are the uniform flux across the surfaces; the radially symmetrical flux that can be expanded in a Fourier-Bessel series; and the problem of prescribed temperatures at the surfaces of the crack. Numerical values are given in table and graph form for evaluating the normal components of the stress (in a direction perpendicular to the plane of the crack) for the uniform heat flow.

G. S. Sved, Australia

647. Sutherland, R. D., and Shook, R. G., Thermo-elastic equations applicable to thick-wall, pointed shells of revolution, AFOSR TN 59–1274 (Convair, Div. General Dynamics Corp. TM–349–14), 29 pp. Nov. 1959.

In the determination of stresses in thick-wall shells of revolution, the problem is made more tractable when a new coordinate system can be introduced which coincides with the surface of the body under consideration. A coordinate system was selected based upon the classic ogive shape which has been in general use for many years for low aerodynamic drag applications. The thermo-elastic equations corresponding to this coordinate system are derived in this paper. Stress-function equations are presented and techniques for handling the boundary conditions are shown.

R. L. Bisplinghoff, USA

648. Ignaczak, J., A plane dynamic problem of thermoelasticity concerning a circular hole (in English), *Bull. Acad. Polonaise Sci., (IV)* **7**, 7/8, 469–475, 1959.

Problem considered is that of determining the distribution of stress in an infinite (two-dimensional) elastic medium containing a circular hole of radius a when a point source of heat is situated at a point distant a' from the center of the circle ($a' > a$). The boundary conditions on the hole are (1) that it is free from stress, (2) that it is maintained at zero temperature. The point source is assumed to have strength $Q_0 e^{i\omega t}$. The basic equations are solved by separating the variables. No numerical calculations are carried out.

From the basic solution, author derives the solution corresponding to an instantaneous line source of heat appearing at time $t = 0$ in the neighborhood of a circular hole.

I. N. Sneddon, Scotland

649. Muller, K.-H., Stresses in an anisotropic circular cylindrical tube (in German), *Ing.-Arch.* **27**, 6, 417–420, 1960.

Paper discusses the plane-strain problem of a circular cylindrical tube which exhibits anisotropy in the cross-sectional plane. Lechnitzki's complex representation of Airy's stress function for an anisotropic medium is used. In a second part of the paper applications will be discussed. Y.-Y. Yu, USA

650. Chattarji, P. P., and Dutt, S. B., On the stresses due to a nucleus in the form of a centre of rotation in an infinite elastic solid with spherical inclusion, *Bull. Calcutta Math. Soc.* **51**, 4, 186–190, Dec. 1959.

Stresses in an infinite elastic solid due to a nucleus in the form of a center of rotation at a finite distance from a spherical inclusion have been studied. To begin with, a general solution has been obtained with an elastic inclusion and hence particular cases of rigid inclusion and cavity have been discussed. Numerical values of the stresses have also been given for a spherical elastic inclusion when $\mu_2/\mu_1 = 2$ and $c = 5$.

From authors' summary

651. Chakravorti, A., Centre of flexure of a beam of orthotropic material having a section bounded by an ellipse and its major axis (in English), *ZAMM* **39**, 7/8, 309–313, July/Aug. 1959.

Following a suggestion of Love, Saint-Venant's semi-inverse method is applied to the flexure problem of orthotropic beams. A coordinate transformation provides a stress function that behaves analogously in the transformed section to the stress function encountered in the flexure of isotropic beams. A general expression is derived for the position of the center of flexure; the semielliptical section is used as an illustration.

G. Sved, Australia

652. Volkov, A. N., Contact problems concerning cylindrical shells of open and closed profile (in Russian), *Inzhener. Sbornik Akad. Nauk SSSR* **27**, 179–184, 1960.

Assuming that the transverse strain and shear, longitudinal bending and twisting moments are negligible the title problem is taken to be given by two simultaneous equations for normal stress and transverse bending moment. Their solutions are taken as product-type functions of longitudinal and angular coordinates. It is stated that the variational equivalent of satisfying the differential equations is to orthogonalize them to the function of the angular coordinate. This leads to a generalized beam-type equation for the function of axial coordinate. A shell with open (semi-circular cross section) and closed regions is considered. Continuity conditions, satisfied again as before, and the boundary conditions determine the solutions for the two regions. A numerical example illustrates the choice of the angular function and the method.

G. A. Nariboli, India

653. Mossakovskii, V. I., On contact rolling of elastic cylinders, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **23**, 5, 1417–1419, 1959. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

The problem of the rolling of a wheel on a rail due to inertia is solved without the assumption of similarity between the wheel and support materials. The wheel and the rail are replaced in the analysis by elastic half-planes.

R. M. Evan-Iwanowski, USA

Viscoelasticity

(See also Revs. 672, 681, 742, 745, 756, 762, 769, 817)

Book—654. Hoff, N. J., editor, High temperature effects in aircraft structures (AGARDograph no. 28), New York, Pergamon Press, Inc., 1958, vii + 357 pp. $12.

The volume is concerned primarily with structural effects of high temperatures which are caused by aerodynamic heating accompanying supersonic flight. It is sponsored by the Advisory Group for Aeronautical Research and Development (AGARD) of the North Atlantic Treaty Organization.

The text consists of sixteen separate chapters, each by a different American or European author, under the editorship of Dr. Nicholas Hoff. Each chapter contains a technical summary of a dis-

tinct topic from the general subject of aerodynamic heating in aircraft and missile structures. These include:

1. Introduction; 2. External sources of heat; 3. Heat transmission in the structure; 4. Materials for high-temperature aircraft structures; 5. Non-metallic structural materials at high temperatures; 6. Glass-like structural materials at high temperatures.

7. Creep and relaxation in metals; 8. Creep and stress relaxation of plastics; 9. Fatigue at high temperatures; 10. Thermal stresses.

11. Buckling caused by thermal stresses; 12. Stress distribution in the presence of creep; 13. Creep buckling; 14. Influence of aerodynamic heating on aeroelastic phenomena.

15. Experimental methods in high-temperature structural research; 16. Models and analogues.

The chapters are technical in content and present the state of progress in each of the above subjects up to the time of publication (1957–58). In some cases, new and original analytical results are presented by the authors. Moreover, after each chapter an extensive bibliography is provided on each subject.

Reviewer feels that this text accomplishes an extremely useful purpose in bringing together in one volume a group of very good technical summaries of the many separate subjects and fields which enter into the analysis of problems arising from the aerodynamic heating accompanying supersonic flight. A careful reading of the text will provide engineers and other research workers in this field with a fairly complete picture of the state of progress up to 1958. The articles are very well written and numerous figures and tables add materially to the clarity of the presentation. The reviewer feels that Dr. Hoff and his colleagues have made a substantial contribution to the literature in this field. This book should find a wide acceptance and use among the people engaged in the field, both in industrial work and in the universities.

M. L. Baron, USA

655. Ma, B. M., A further creep analysis for rotating solid disks of variable thickness, *J. Franklin Inst.* **269,** 5, 408–419, May 1960.

Creep strains in a variable-thickness solid rotating disk (with no bore) are analyzed by using the Tresca (maximum shear stress) criterion, assuming creep rate to be an exponential function of the effective stress (applicable at relatively high temperatures). Stress distributions are determined and plotted for the steady-state condition with uniform temperature, using a hyperbolic profile. Comparisons with the flat disk are made. Maximum tangential stresses are found to be higher than those obtained by using the Mises criterion (octahedral shear stress).

F. R. Shanley, USA

656. Mulhearn, T. O., and Tabor, D., Creep and hardness of metals: a physical study, *J. Inst. Metals* **89,** 7–12, 1960/1961.

In a study of the effect of time of loading on the indentation hardness of metals, measurements have been carried out on indium and lead from liquid-air temperature to 50 °C below the melting point. A spherical indenter was used and loading times were varied from 10^{-4} to 10^{3} sec. Apart from some preliminary experiments, the study was confined to single crystals. In general, the hardness or yield pressure p decreases with loading time t. Above $\sim 0.6\ T_m$, where T_m is the melting temperature (°K), and for times of loading exceeding a few seconds, a linear relationship exists between $\log p$ and $\log t$. In this temperature range, experiments carried out at various temperatures give a series of parallel lines, the separation between them providing a measure of the activation energy involved. The values obtained are 16 kcal/mole for indium and 28 kcal/mole for lead, which are close to the activation energies for self-diffusion. Metallurgical examination shows that there is negligible recrystallization or other grain-boundary effects during the course of one experiment. The deformations around the indentation correspond to slip, suggesting that the rate-limiting process to creep in this temperature range is dislocation climb. If the loading time is reduced below ~1 sec, there is a marked rise in hardness, and for values of t less than $\sim 10^{-3}$ sec an upper limit to p is reached (p_{max}) which is the same whatever the initial temperature of the experiment. In the case of indium the deformation also changes from slip to twinning. If hardness measurements are made at liquid-air temperature, the hardness is almost independent of loading time and is roughly equal to p_{max}. With indium the deformation at these low temperatures occurs by twinning, whatever the loading time. It is apparent that for temperatures $> 0.6\ T_m$ the creep process is dominated by a self-diffusion mechanism. If the loading time is too short or if the temperature is very low, this mechanism cannot operate and the hardness is greatly increased.

From authors' summary

657. Mendelson, A., Hirschberg, M. H., and Manson, S. S., A general approach to the practical solution of creep problems, *ASME Trans.* **81** D (*J. Basic Engng.*), 4, 585–598, Dec. 1959.

Given a particular yield criterion or creep law (Tresca's, von Mises'), together with initial and boundary conditions, elastic constants, etc. needed for solution of the corresponding purely elastic problem, a unique solution to the plastic problem (with creep) does exist. Authors provide a practical way of finding this solution. As chief example they study a rotating annulus originally of constant thickness.

All the equations used for the solution are given in detail. The idea is to find creep strains in each increment of time, not by satisfying simultaneously all the equations which must be satisfied, but by a simple method of successive approximation.

It is found that neglect of the very small amount of elastic strain can materially affect the value of the strain computed after a very long time. This is so because the ultimate stresses are changed slightly, and in the creep equation these stresses are raised to a high power and multiplied by the elapsed time.

Plastic strain ε is found eventually as the sum of incremental strains $\Delta\varepsilon$. To compute the latter by iteration, the time increment must be small enough for convergence. Truncation error in computing $\Delta\varepsilon$ is not considered.

On the whole, the paper has both practical and didactic importance.

J. L. Brenner, USA

658. Hunter, S. C., Possible equation to describe transient stress, strain and temperature fields in viscoelastic solids, Brown Univ., Div. Appl. Math. TR 2 (Contract NOrd 18594), 47 pp., Jan. 1960.

Constituent equations are synthesized from Boltzmann equations of linear viscoelasticity, Ferry temperature shift relation and thermal expansion relation. Description is completed by equations of motion and diffusion equation, latter including not only the elastic "thermomechanical coupling" term, but a term representing the dissipation of energy peculiar to viscoelastic materials. Equations are applied to creep, stress relaxation, and periodic deformations, and temperature variations are investigated. Propagation of P-waves is treated with linearized equations, and it appears that the effect of "thermomechanical coupling" in most cross-linked polymers is a *reduction* in attenuation, much greater than the *increase* found in purely elastic solids by Chadwick and Sneddon [AMR **12**(1959), Rev. 2883].

D. S. Berry, England

Plasticity

(See also Revs. 701, 704, 742, 744)

659. Shield, R. T., Plate design for minimum weight, *Quart. Appl. Math.* **18,** 2, 131–144, July 1960.

The theory of minimum weight (minimum volume) design of plate is discussed. It is assumed that the plate is a sandwich plate consisting of a core of a given constant thickness and identical

face sheets of variable small thickness. The core carries shear force only. A bending moment across a section of the plate is supplied by direct stresses in the face sheets. The face sheets obey Tresca's yield condition. Computation is based upon a theorem previously proved [AMR **10**(1957), Rev. 420 and **12**(1959), Rev. 5024] which states that minimum volume of face sheets will be involved if the rate of dissipation of energy per unit volume has a constant value throughout the plate. The boundary line of the plate has a general shape (the case of circular plate was treated in previous papers). Computation is fully carried out for an elliptical plate with clamped boundary. J. Barta, Hungary

660. Olszak, M. W., and Sawczuk, M. A., Theory of the strength of nonhomogeneous orthotropic constructions (synthesis and analysis) (in French), *Ann. Inst. Tech. Bât. Trav. Publics* **13**, 149, 517–536, May 1960.

This is a condensed version of most of the practically important results obtained by Professor Olszak and his collaborators on the limit analysis and design of nonhomogeneous and orthotropic rigid-plastic plates and shells subjected to proportionally increasing loads. Throughout the paper, most proofs and intermediate calculations are omitted for the sake of brevity and the reader is referred to the original Polish literature.

First, generalizations of the fundamental lower and upper bound theorems of Gvosdev, Greenberg, Drucker and Prager are offered without proof. Then they are applied to circular, rectangular and ribbed nonhomogeneous and orthotropic plates and accurate lower and upper bounds of their limit loads are given. The problem of mushroom slabs is also studied. Finally, the fundamental theorems are applied to thin orthotropic cylindrical shells and to a nonhomogeneous shell.

In the opinion of the reviewer, the main value of this paper lies in the fact that new solutions of difficult problems of applied plasticity are presented in a form adapted to direct practical application by structural engineers and designers.

C. E. Massonnet, Belgium

661. Mroz, Z., On a problem of minimum weight design, Brown Univ., Div. Appl. Math. TR 59 (Nonr 562 (10) (NR-064-406)), 18 pp., May 1960.

Extremum principles are applied to investigation of design for minimum weight. Consider rigid perfectly plastic body C with mixed boundary conditions; surface $S_c = S_t$ (tractions, $\neq 0$, prescribed) + S_u (zero velocities) + S_c' (stress free); requirements for statically admissible stress, and kinematically admissible velocity, fields are met. Using either or both of two standard theorems of limit analysis, author proves that D (plastic dissipation of velocity field) equals some constant $\overline{D}$ over S_c', exceeds $\overline{D}$ within volume V, and that, if $D < \overline{D}$ beyond S_c', then C has minimum volume obtainable if given loads do not exceed limit loads. But for plates and shells, D over S_c exceeds D within V; for such, author proves that, if $D = \overline{D}$ on S_c', then V attains local maximum or minimum, provided S_c' is suitably chosen. Limit design of plates is discussed and particularized to the case of transversely loaded simply supported circular plates for both Tresca and Mises yield conditions.

Brief note on shells and good list of references conclude this report which can be confidently recommended both for subject matter and for clarity of exposition.

F. A. Gerard, Canada

662. Neal, B. G., and Symonds, P. S., Cyclic loading of portal frames: Theory and tests (in English), *Publ. Int. Assn. Bridge Struct. Engng.* **18**, 171–199, 1958.

Authors demonstrate, analytically, that incremental collapse can occur under the cyclic application of loads which are smaller in magnitude than those required for plastic collapse. Experiments performed on portals constructed of mild steel agree qualitatively with theory. It seems to the reviewer that the results of the paper complicate the task of the designer. A host of problems such as sequence of loading, magnitude of loading, and probability of occurrence of loadings must now be considered. The interesting question remains: are plastic design methods still advantageous if incremental collapse is possible? J. W. Mar, USA

663. Ivlev, D. D., On the development of a theory of ideal plasticity, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **22**, 6, 1221–1230, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

In this work some extremal properties of an ideal plastic flow satisfying Tresca's plasticity condition are considered. These properties distinguish Tresca's plasticity condition from a class of other admissible plasticity conditions which author defines.

From author's summary by R. M. Evan-Iwanowski, USA

664. Shaffer, B. W., and Ungar, E. E., Mechanics of the sheet-bending process, *ASME Trans.* **82** E (*J. Appl. Mech.*) 1, 34–40, Mar. 1960.

The springback of wide sheets that have been bent plastically to a constant radius of curvature is analyzed. An ideally plastic material (flat-topper stress-strain diagram) during loading is assumed and Tresca's criterion (maximum shear stress = const) is applied. It is shown that the usual assumption of elastic unloading over the entire thickness is not valid, because the neutral surface does not have the same position during loading and unloading. This causes certain zones to remain plastic, i.e. to undergo no change in sign of stress. The results are presented in dimensionless form and approximate simplified expressions are given. General conclusions obtained from less accurate analyses remain substantially unchanged. F. R. Shanley, USA

665. Zanaboni, O., Aspects and consequences of the variational formulation of the congruency (in Italian), *G. Gen. Civ.* **97**, 11, 918–926, Nov. 1959.

Menabrea's theorem and Saint-Venant's principle of the theory of elasticity are extended to a very general class of deformable media. D. Gh. Ionescu, Roumania

666. Davydov, I. V., Determination of the displacements in compressed deflected components during their work beyond the limits of elasticity (in Russian), Sb. Inform. Soobshch. o Nauchno-issled. Rabotakh. Vypolnen. Vyssh. Uchebn. Zavedeniyami. Stroit. Konstruktsii, Kiev, 1958, 47–50; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 3008.

A brief description is furnished of the work dealing with the determination of the elasto-plastic displacements in bars, made from ideally elasto-plastic material, during the joint action of deflection and tension. The Moore-Maxwell formula is used for the calculations, the formula being generalized to cover the case of deformation beyond the limits of elasticity. The concept of the "adduced moment" is utilized and by analogy the concept of the "adduced longitudinal force" is introduced. For a bar of rectangular transverse section an expression is brought in for the calculation of the magnitude of the adduced moment in relation to the magnitude of the acting deflection moment and longitudinal force. For cases of loads which impart a rectilinear or parabolical character to the curves of the moments, formulas are advanced for the calculations of the areas of the curves of the adduced moments and their centers of gravity, which simplify the computations for the Moore-Maxwell integrals. Yu. K. Rakovshchik

Courtesy Referativnyi Zhurnal, USSR

667. Bykov, V. A., and Artem'ev, N. S., The influence of the curvature of the convolution on the plastic stability of compression springs (in Russian), *Trudi Leningrad Korablestroit. In-ta* no. 20, 193–203, 1957; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 3256.

It is proposed to determine the correction coefficient which takes account of the curvature of the convolution in the formula for the maximum stresses in the spring as the relation of the nominal stress causing the determined residual deformation in the straight wire to the nominal stress causing the same deformation in a spring with an assigned index. In this procedure the magnitude of stress in the straight wire is determined by extrapolation in accordance with the results of tests of springs with different indices. It has to be noted that the coefficient calculated in the above manner does not characterize the magnitude of the maximum stresses in the section.

V. L. Biderman

Courtesy Referativnyi Zhurnal, USSR

668. Alekseev, Yu. N., The spring effect when bending articles on three rollers (in Russian), *Trudi Khar'kovsk. Aviats. In-ta* no. 17, 215–224, 1957; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 3027.

An investigation is made of the elasto-plastic deformations of articles being bent on a bench by means of three rollers when the article is in motion. The link is established between the maximum deflection and the magnitude of the residual radius of the article's curvature. This scheme of deformation of an article being bent on a bench is assumed to be analogous to the deflection of a beam resting on two supports, loaded centrally by a force. It is shown that in the case where the deformation moves along the length of the beam considerable differences are noticeable when compared with the deformations on an immovable beam. For an immovable beam the deformation in sections which are symmetrical in relation to the center is identical. When motion in the section of the beam is taking place, the transposition being in the direction of the place where the load is being applied, the deformation is determinable from the state of loading, while in a section which has passed the place of the application of the load the deformation is determinable from the state of unloading, and in this case the deformations in the sections, symmetrical in relation to the center, will be different. The relation is evolved of the dependence of the radius of curvature of the section on the coordinates' function by the length, and the curved axis of the beam is determined. It is shown that, with even loading, in the case of motion of the beam the magnitude of its curvature appreciably exceeds the value of the curvatures of the immovable beam. The theoretical calculations correspond with the experimental data.

Yu. A. Rakovshchik

Courtesy Referativnyi Zhurnal, USSR

669. Bol'shanina, M. A., and Panin, V. E., The latent energy deformation (in Russian), Issled. po Fiz. Tverdogo Tverdogo Tela., Moscow, Akad. Nauk SSSR, 1957, 193–233; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 3047.

The article is in the form of a survey. Accounts are given of the determination of the latent energy of deformation (in the actual process of deformation by observation on the state of the material after deformation using the annealing method) and the principles of absorption of energy during plastic deformation (the magnitude of the latent energy, its relation to the amount and form of the deformation, to the melting point temperature and the test temperature to the velocity of deformation, to the velocity and temperature of the preliminary deformation; energy absorption during the deformation of alloys, the influence of external friction, the thermal stability of the latent energy). The nature of the latent energy of deformation is explained with the aid of the theory of dislocation and is linked up with the formation of voids and dislocated atoms produced by accumulations of impeded dislocations.

N. N. Davidenkov

Courtesy Referativnyi Zhurnal, USSR

670. Kliushnikov, V. D., New concepts in plasticity and deformation theory, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **23,** 4, 1030–1042, 1959. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

A comparative analysis of some conclusions of three new theories of plasticity: Batdorf and Budiansky's slip theory, Slander's theory based on linear loading function and the theory proposed by Kliushnikov [title source, **23,** no. 2, 1959] and a model representation by Rabotnov [title source, **23,** no. 1, 1959]. A new role of the Hencky-Nadai theory in the general relationships of plasticity is determined.

R. M. Evan-Iwanowski, USA

671. Kurkin, S. A., and Vinokurov, V. A., Deformation of thin-sheet components when welded, and remedial measures to counteract the same (in Russian), *Svarochnoe Proiz-vo* no. 4, 28–31, 1958; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 3264.

Calculations show that the curvature due to general distortion when welding increases with increase of the thermal stresses and with decrease in the thickness and width of the sheets; the free shrinkage of the seams is several times greater than the shrinkage of the sheets in a compressed condition. Decrease in distortion is effected by removal of the residual stresses by rolling of the seam and the zone adjacent to it (after the completion of the weld) or by the compression of the welding spots. A special machine was constructed capable of rolling out the seams along their breadth, or when circular and when the seams are in a shell-shaped body.

A. Ya. Brodskii

Courtesy Referativnyi Zhurnal, USSR

672. Besseling, J. F., A theory of elastic, plastic, and creep deformations of an initially isotropic material, AFOSR TN 60–384 (Stanford Univ., Dept. Aero. Engng. SUDAER no. 78), 36 pp., Apr. 1958.

Stress-strain relations are given for an initially isotropic material, which is macroscopically homogeneous, but inhomogeneous on a microscopic scale. An element of volume is considered to be composed of various portions, which can be represented by subelements showing secondary creep and isotropic work-hardening in plastic deformation. If the condition is imposed that all subelements of an element of volume are subjected to the same total strain, it is demonstrated that the inelastic stress-strain relations of the material show anisotropic strain-hardening, creep recovery, and primary and secondary creep due to the nonuniform energy dissipation in deformation of the subelements. Only quasi-static deformations under isothermal conditions are considered. The theory is restricted to small total strains.

From author's summary by A. P. Boresi, USA

Rods, Beams and Strings

(See also Revs. 651, 708, 711, 712, 715, 717, 726, 783, 798)

673. Glushko, M. F., Questions relating to the strength of sinking haulage cables in mine shafts (in Russian), *Nauchn. Dokladi Vyssh. Shkoly. Gorn. Delo* no. 2, 173–184, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6966.

The case is investigated of the work of a cable where the bucket moves along without guides and the cable not only stretches but also untwists. The author shows that here the twisting moment can be balanced by the internal forces in the cable, and if the strands of the internal and external layers are woven in opposite directions the internal strands will be stressed to a greater extent. The author proposes, by changing the direction and angles of the weaving pattern and also the other parameters, to make a cable in which the twisting moment is balanced; he also carries out a check calculation for the rupture of the inner layer only of the woven cable under the action of the whole of the end load. When carrying this out a safety factor is proposed equal to 2 to 3.

N. P. Dinnik-Grishkova

Courtesy Referativnyi Zhurnal, USSR

674. Nikitin, S. P., Calculations of bimetallic ropes (or cables) (in Russian), Strength calculations (Raschetyi va Prochnost', no. 2), Moscow, Mashgiz, 1958, 222–232; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6969.

The problem is approximately solved for the evaluation of the magnitude of the destruction load when a bimetallic (steel-aluminum) rope is stretched. The tests showed a small divergence between the test data and the calculation.

From author's summary

675. Payne, L. E., Upper and lower bounds for the center of flexure, *J. Res., Nat. Bur. Stands.* **64** B (*Mathematics & Mathematical Physics*), 2, 105–111, Apr./June 1960.

It is well known that there exist at least two methods of defining the concept of the center of flexure of an isotropic elastic beam. One method is due to Trefftz [*ZAMM* **15,** p. 220, (1935)], the other method is due to Goodier [*J. Aero. Sci.* **11,** p. 273, (1944)]. Author derives upper and lower bounds for the coordinates of the center of flexure for both definitions.

A. Phillips, USA

Book—676. Vlasov, V. Z., and Leont'ev, N. N., Beams, plates, and shells on elastic foundations [Balki, plity i obolochki na uprugom osnovanii], Moskva, Gosudarstvennoe Izdatel'stvo Fiziko-Matematicheskoi Literatury, 1960, 491 pp. 16 r. 35 k.

The first chapter briefly summarizes common elasticity relations and discusses solutions in the form of separation of variables. The Boussinesq problem is considered in detail and the concept of single- and double-layered elastic foundations discussed. In the latter the elastic constants of the two layers are distinct. The second chapter introduces the usual linear equation for the beam on an elastic foundation. Many boundary-value problems are solved for beams of finite length in much the same manner as presented in "Beams on elastic foundations," by M. Hetenyi, 1946, but no reference is made to this book.

The bending of rectangular plates on single-layered elastic foundations is considered in chapter three. One approximate method introduced is to represent the deflected plate in terms of normal modes of free vibrations of beams in the two orthogonal directions. Several problems involving finite dimension rectangular plates as well as infinitely long plates undergoing cylindrical bending are solved.

The fourth chapter treats the axisymmetric bending of circular plates on single-layered foundations. Only small axisymmetric deformations are considered. Several problems of flexible plates subject to axisymmetric load are solved in terms of the functions originally presented by Schleicher. Lastly, several variations of the problem of a rigid circular punch acting on the foundation are investigated. The fifth chapter investigates the axisymmetric deformations of shallow spherical shells on single-layered elastic foundations. Linearized theory is again used and numerous boundary-value problems are solved in terms of Bessel functions of either real or imaginary arguments.

Chapter six treats the vibrations and buckling of beams and plates on elastic foundations. Beam vibration problems are solved by the usual separation-of-variables procedure for a variety of boundary conditions. Several problems of the free vibrations of rectangular plates are solved in the same fashion. The stability of a rectangular plate resting on a single-layered foundation and subject to in-plane compression parallel to one of its sides is solved by assuming a deflected shape in the form of a double Fourier series and determining coefficients by a minimum energy technique. The book concludes with a presentation of extensive tables to aid in the numerical analysis of the various problems considered.

The book reports, in general, only the work of the authors and certain of their colleagues. There is not a single reference to the abundance of Western literature in this field. No new techniques of solution are presented. W. A. Nash, USA

677. Kammel, G., A contribution to the theory of twisted bars (in German), *Ing.-Arch.* **27,** 4, 255–267, 1959.

We have here yet another proposal for a generalized form of the relations between convenient measures of stretch, shear, bending and twist in an initially twisted bar and the corresponding normal and shear forces, bending and twisting moments. In the intention of the author the generalization should be relevant in a study of thick bars; however, he retains the classical hypothesis of plane normal sections and disregards the effect of shear forces on the deformation. Author's approach is as follows: having ideally divided the bar in "strings" of infinitesimal cross section he obtains an expression for the strain in each string and assumes the string's tension to be proportional to the strain; by integration over the cross section the relevant (extremely complex) relations are obtained. G. Capriz, England

678. Chakravorti, A., Note on the torsion of curved rods composed of anisotropic material with oval sections, *Bull. Calcutta Math. Soc.* **51,** 4, 161–166, Dec. 1959.

Stresses and displacements associated with the twist of curved anisotropic rods having sections of oval type are obtained in this note. From author's summary

679. Ismailov, M. U., Determination of the stresses in a twisted round bar, weakened by a prismatically shaped hollow (in Azerb.), *Ucb. Zap. Azerb. In-ta* no. 11, 39–48; 1957; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 2897.

The problem is investigated of the torsion in a slanting bar of constant transverse section S, bounded from outside by a space L_1, with radius R and from inside by a curvilinear square L_2. D. I. Sherman examined the analogous problem of a curvilinear square with slightly rounded entry angles [*Izv. Akad. Nauk, Otd. Tekh. Nauk* no. 7, 1951]. By employing instead of the function

$$\omega(\zeta) = A\left(\zeta + \tfrac{1}{9}\,\zeta^{-3}\right)\left(A = \tfrac{1}{2}\,(a+b)\right)$$

where a is the semidiagonal, b half the side of a curvilinear qquare, used by D. I. Sherman, the function

$$\omega(\zeta) = A\,(\zeta + 0.151\,\zeta^{-3} + 0.01\,\zeta^{-7} + 0.001\,\zeta^{-11})$$

reflecting the exterior of the curvilinear square on the exterior of the unit circle, the author, using the D. I. Sherman method effects a solution of the problem set, taking the calculations to their end point. It was shown that decreasing the rounding off of the entry angles of the curvilinear square increases the stress concentration at the given points. A. K. Rukhadze

Courtesy Referativnyi Zhurnal, USSR

Plates, Shells and Membranes

(See also Revs. 587, 591, 594, 642, 644, 647, 652, 655, 659, 661, 664, 676, 703, 704, 705, 708, 720, 723, 727, 728, 729, 741, 782, 790, 798, 799, 805, 1103)

Book—680. Pfluger, A., Elementary shell theory [Elementare Schalenstatik], 3rd ed., Berlin, Springer-Verlag, 1960, viii + 112 pp. DM 19.50.

This third edition of the well-known book differs from the second edition [AMR **11**(1958), Rev. 2036] only in a few unimportant corrections. The very clear presentation of elementary problems and the excellent tables of formulas for membrane stresses for many different types of shells and loads makes the book valuable for the practicing engineer as well as the student. It can be warmly recommended. E. R. Steneroth, Sweden

Book—681. Gol'denblat, I. I., and Nikolaenko, N. A., Creep and load-carrying capacity of shells [Polzuchest'i nesushchaya

sposobnost' obolochek] Moskva, Gosudarstvennoe Izdatel'stvo Literatury po Stroitel'stvu, Arkhitekture i Stroitel'nym Materialam, 1960, 58 pp. 2 r 10 k. (Paperbound)

The monograph is divided into three sections. The first treats the general theory of thermal strains, plasticity, and creep of shells. Equations of equilibrium are formulated in tensor notation for curvilinear coordinates, with a consideration of thermally-induced strains as well as variations of elastic properties with temperature. The second section treats the creep of membrane shells. Equilibrium equations are derived for (a) viscoelastic materials, (b) elastic but hereditary-type materials, and lastly (c) materials termed by Zener "standard linear solids" although described here as Ishlinsky-type materials. Unfortunately the treatment terminates with the formulation of these equations. No boundary-value problems are investigated. In the third section the treatment of the second section is extended to a shell capable of resisting bending. Again, no boundary-value problems are solved.

W. A. Nash, USA

Book—682. Mushtari, Kh. M., and Galimov, K. Z., Nonlinear theory of elastic shells [Nelineinaya teoriya uprugikh obolochek] Kazan, Tatknigoizdat, 1957, 431 pp. 13 rub. 40 kon.

Finite deflections of shallow shells of various contours as well as flat plates are treated in this book. In general, it gives a survey of significant accomplishments in this field up to the date of publication. The book is reasonably well documented with references to Western as well as Soviet literature.

The differential geometry of the deformed shallow shell is developed and nonlinear strain-displacement relations obtained for the case of orthogonal curvilinear coordinates. Equilibrium equations are obtained for the case of small strains and arbitrary bending. Also presented is a unique discussion of the errors committed by treating shallow shells as plates with initial imperfections.

These introductory chapters are followed by two chapters treating the finite deflections of rectangular and circular plates. Many cases of lateral deflections of plates subjected to transverse loads as well as loads in the plane of the plate are treated in detail. The method of attack employed is usually a perturbation-type procedure, although some energy solutions are presented.

The following chapter treats various loadings leading to instability of cylindrical shells of medium length, i.e. the shells are sufficiently long that edge conditions are considered to be unimportant. Finite deflection theory is employed throughout and the more significant results from the literature are presented in detail. The next chapter extends these treatments to the case where initial imperfections are present in the cylindrical shell. The finite deflections of a shallow cylindrical panel subjected to various combinations of normal and shear forces as well as transverse pressure are treated for a number of cases.

The next chapter develops the nonlinear equations required to treat the stability of a conical shell of circular cross section. Various cases of axisymmetric buckling due to axial compression as well as normal pressure are discussed. The case of the conical shell of linearly varying thickness subject to uniform normal pressure is discussed. The book concludes with a chapter devoted to the stability of shells of revolution, treated from the standpoint of nonlinear theory. The only problem treated in detail is that of the shallow spherical cap subject to uniform normal pressure. The mode of attack follows that used by von Karman and Tsien in 1939.

In all, the book presents a reasonably complete resume of existing knowledge in the field of elastic buckling of thin shells subject to static loadings at room temperature. There are no discussions of creep buckling or dynamic buckling.

W. Nash, USA

683. Tamoroglu, S., Membrane and bending theory of circular cylindrical shells for nonlinear elasticity (in German), *Ing.-Arch.* **27**, 6, 372–384, 1960.

On the basis of the nonlinear stress-strain relations for small deformations as formulated by H. Kauderer ["Nichtlineare Mechanik," 1958; AMR **12**(1959); Rev. 1130] membrane equations for shells of revolution and axially symmetrical bending equations for cylindrical shells are developed. The latter equations are finally reduced to a single equation involving only the radial displacement, which is further reducible to the usual simple form of the linear case, and for solving which a procedure of sucesssive approximation is indicated. No numerical examples are given.

Y.-Y. Yu, USA

684. Mishonov, M., The practical calculation of bending moments in shells of rectangular planform (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **27**, 162–170, 1960.

Shells having a rectangular planform, constant principal curvatures and supported along lines of principal curvatures are considered. An approximate differential equation of bending is written which has to be applied only in the neighborhood of supported edges. This equation has the form of the differential equation of a beam on elastic foundation with an additional constant term, whose value is obtained from membrane theory. The method gives quick results.

Natalija Naerlovic, Yugoslavia

685. Callari, C. E., Development and evaluation of an approximate analysis of thin, cylindrical shells (in Italian), *G. Gen. Civ.* **97**, 11, 945–962, Nov. 1959.

The central assumption of the beam method of analysis of long cylindrical shells [cf. Lundgren, "Cylindrical shells," Danish Technical Press, Copenhagen, 1951] is the straight line distribution of normal longitudinal stresses. In the case of shells with edge beams it may be more appropriate to assume this distribution to consist of two straight lines meeting at the point of intersection of edge beams and the shell proper. This assumption was used by Barets [*Ann. Inst. Tech. Bât. Trav. Publics*, no. 122, Feb. 1958] and, in a more general form, by Jenkins [cf. AMR **13**(1960), Rev. 125].

The paper under review applies the Barets approach to a somewhat more general case without restrictions on boundary conditions. General formulas are derived. Method is applied to a single barrel with edge beams; comparison of numerical results with those of Lundgren, ASCE and experimental analyses indicates improved accuracy, particularly in transverse bending moments. A study of nonsymmetrical state of stress is to be published at a later date.

S. J. Medwadowski, USA

686. Mortelmans, F., Shells forming surface of revolution on polygonal base (in Dutch), *Ann. Trav. Publ. Belgique* no. 3, 219–272, June 1959.

The shells are of constant thickness. Bending and torsion is neglected and an ample treatment of the membrane theory is given. The meridian curve may be a circle, a parabola and a cone. Further the author takes a curve between the parabola and the cone (without a sharp apex). The load is rotationally symmetrical.

Solutions, also rotationally symmetrical, are given with formulas and with tables. Boundary conditions at the base of the shell may be such that nonsymmetrical stresses are introduced. Such perturbation stresses are calculated in the form of Fourier series for different boundary conditions.

J. P. Benthem, Holland

687. Valenta, J., Theoretical solution of a segment of a circular cylindrical shell with a thick wall (in German), *Ceskoslov. Akad. Ved, Aplik. Mat.* **6**, 3, 461–476, 1958.

The author considers a segment cut from an infinitely long thick-walled circular cylinder by two planes passing through the cylin-

der axis and equally distant on each side of a reference plane. The loads on the interior and exterior surfaces are distributed symmetrically with respect to the reference plane and do not vary along the cylinder axis but are otherwise arbitrary. This allows all quantities to be represented in a Fourier cosine series. The boundary conditions on the plane edges are taken to be such that they also do not vary along the cylinder axis. The body is therefore in a state of plane strain.

The solution can be found by superposition of a particular solution satisfying the given conditions on the surfaces and a "homogeneous solution" which satisfies the condition of zero stress on the surfaces but contains sufficient arbitrary constants to satisfy arbitrary conditions on the plane edges. The author shows how a particular solution to the plane stress equations can be found. He then suggests a means of constructing a certain class of "homogeneous solutions." No numerical examples are given.

E. H. Dill, USA

688. Myzin, A. K., Analysis of elastic cylinders (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **26**, 87–93, 1958.

Two cylinders connected by transverse bolts are considered (rocket parts may be such a case).

Assumption is made that the shells work as membranes and that shear forces occur in the bolts, proportional to the difference of the relative displacements of cylinders. These forces appear in the equations of the membrane theory of cylinders as external loads. In the interior, the pressure and temperature are considered as differing from the intermediate and external zones.

The general integrated expression of the resultant stresses and of the transverse forces in bolts is obtained. Examples are given for three types of end conditions.

Reviewer believes that a more accurate solution for the load theory would also take into consideration the bending effect produced by the bolts, which in the already accepted hypotheses of the dense distribution could be of importance.

M. M. Misicu, Roumania

689. Morley, L. S. D., The thin-walled circular cylinder subjected to concentrated radial loads, *Quart. J. Mech. Appl. Math.* **13**, 1, 24–37, Feb. 1960.

Earlier [AMR **12**(1959), Rev. 5458] the author developed an approximate equation for the radial displacement component of a thin cylindrical shell subject to arbitrary loading. This new equation represents an intermediate approximation between the more accurate equation of Flügge and the well-known equation of Donnell, retaining the simplicity of the Donnell equation but possessing a greater range of validity. The present paper is an application of the author's equation to an infinite cylinder and yields rather simply a solution which compares quite favorably with one obtained by Yuan and Ting [AMR **10**(1957), Rev. 2480] using the Flügge equation. The results for the displacement under the load also agree with those obtained more recently by Ting and Yuan [AMR **12**(1959), Rev. 98] using the "complete Donnell equation," the latter representing an approximation somewhat similar to the author's approximation.

R. A. Clark, USA

690. Kennard, E. H., Tripping of T-shaped stiffening rings on cylinders under external pressure, David W. Taylor Mod. Basin Rep. 1079, 33 pp., Nov. 1959.

Approximate theory is developed for lateral deformation of T-shaped ring attached to inside or outside surface of cylindrical shell subjected to uniform external pressure. Failure by yielding of a ring attached with initial tilt, and failure by lateral elastic buckling of an untilted ring, are investigated. Equations of equilibrium are derived for lateral deformation, and stability criterion is based on method of adjacent equilibrium. Neither initial tilt nor deformation is restricted to axial symmetry. Results are given in equation form, and a numerical example is presented. Author concludes that in practical cases results appear not to differ markedly from those of axisymmetric case, which was treated in an earlier report, AMR **10**(1957), Rev. 3597.

D. O. Brush, USA

691. Bassali, W. A., and Gorgui, M. A., Flexural problems of circular ring plates and sectorial plates, Part 1, *Proc. Camb. Phil. Soc.* (Math. Phys. Sci.) **56**, 1, 75–95, Jan. 1960.

Small-deflection theory of thin isotropic plates in the form of circular annuli and annular sectors as well as of unbounded wedge-shaped annular sectors is discussed using the complex variable method of Muskhelishvili. A large variety of boundary conditions is considered (embracing a general elastic fixing), while the load consists of: (a) a concentric line pressure of intensity $p_0 \cos k\theta$ (p_0 = constant, θ angle in $[0.2\pi]$, $k = 0, 1, 2, \ldots$); (b) a similarly distributed arcwise pressure $p_0 \cos s\theta$ with θ in $[-\alpha, \alpha]$; and (c) an isolated point force. Limiting forms of the resulting solutions are found to be in agreement with the known solutions (except for the plate in the form of a circular sector simply supported on the straight edges and free along the circular edge).

J. Nowinski, USA

692. Green, B. I., and Silberstein, J. P. O., Further information on the deformation of thick circular plates, Aero. Res. Lab., Melbourne, Austral., Rep. SM. 271, 17 pp., Sept. 1959.

Authors extend the problem of a uniformly thick circular plate under its own weight supported on an inner rigid annulus (which they studied previously, see AMR **13**(1960), Rev. 2774) to include a simple support on the outer circumferential edge. A superposition of four solutions given in the first paper gives the new analytical solution. Purpose of the extra support was to reduce deflections outside the annulus. Method of analysis is the same as that used previously.

Numerical results are given for a 74-inch diameter, 12-inch thick optical reflector, which provides interesting application of thick plate theory. However, no experimental results are given to verify the theoretical results.

Reviewer believes that energy methods would yield same degree of accuracy with less effort.

D. Frederick, USA

693. Zienkiewicz, O. C., Comparative study of a segmental arch ring, *Proc. Amer. Soc. Civ. Engrs.* **86**, EM 1 (*J. Engng. Mech. Div.*), 19–39, Jan. 1960.

Author makes a comparative study of three commonly used systems of shell equations attributed to Fluegge, Timoshenko and Donnell which are employed to solve the case of hydrostatic pressure acting on a segmental arch ring. All three are based on the generally accepted assumptions regarding the behavior of thin shell elements. Author dwells on the incorrectness of Donnell's equations which is apparent when dealing with a complete ring or in the case of no load. When comparing deflections, Timoshenko and Fluegge's theories give identical results, while Donnell's theory gives some discrepancy which becomes larger as the central angle increases. Results for angles of 45°, 60°, 90°, 180° are plotted for displacements and moments and discrepancies shown. When computing thermal stresses, the use of Fluegge's relationship tends to lead to less accurate results than those obtained by the simpler Timoshenko relationships.

M. Maletz, USA

694. Ling, C.-B., and Tsai, C.-P., Stresses in a slab having a spherical cavity under circular bending, *ASME Trans.* **82** E (*J. Appl. Mech.*), 2, 278–282, June 1960.

Solution is represented by stress function which is constructed by using two series of periodic biharmonic functions and a biharmonic integral and illustrated by numerical examples for two spherical cavities of radii $\lambda a = \frac{1}{4} a$ and $\lambda a = \frac{1}{2} a$, where $2a$ is a thickness of the slab.

The effect of the cavity on the stresses in the slab is shown by two maximum stresses σ_r and σ_θ, which are computed and presented in table for $\lambda = 0$, $\lambda = \frac{1}{4}$, and $\lambda = \frac{1}{2}$, and in graph. The graph shows two curves of maximum stress for values of λ from 0.1 to 0.6. The curves are for a point at zenith of the cavity and a point at a pole of the cavity.

The bibliography refers to one book and seven papers, four of which were written by C.-B. Ling. P. G. Shuleshko, USA

695. Levin, E., Elastic equilibrium of a plate with a reinforced elliptical hole, *ASME Trans.* **82** E (*J. Appl. Mech.*), 2, 283–288, June 1960.

A solution for an infinite thin plate (of material with E_1 and ν_1) with elliptical hole reinforced by a confocal elliptical ring (of material with E_2 and ν_2) is considered. The treatment has been carried out in full generality to include arbitrary dimensions of the ring and arbitrary loading at the hole and at infinity. A solution to generalized plane-stress problem is obtained using the method of Muskhelishvili. The solution for a thin plate with a circular hole reinforced by a circular ring is obtained as particular case from the general solution and is shown, for a negligibly thin reinforcement, to be in agreement with results obtained by other authors.

The result of the solution is presented in the form of equations suited to evaluation by digital computers. Numerical examples are not given. Curves of maximum mean stresses (S_{max} and T_{max}) as functions of the ratio $s = H/b$ (H is thickness of the ring, b is thickness of the plate) are presented for three loading cases (uniform uniaxial tension, equal biaxial tension, and pure shear). The values of stresses at $s = 1 (H = b)$ agree with the solution of Kirsch for the unreinforced plate.

The bibliography refers to one book and eleven papers.
P. G. Shuleshko, USA

696. Hicks, R., The bending and twisting of a flat elastic plate with a reinforced circular hole, *Aero. Quart.* **11**, 2, 137–158, May 1960.

Solutions are given to several problems of pure bending and torsion of a thin plate with a circular hole containing a reenforcing ring of negligible width (compared with its radius). Such problems, for the case of rings of *finite* width, have been thoroughly explored in chapter 7 of G. N. Savin's book, "Stress concentration around holes," Moscow, 1951 [AMR **5**(1952), Rev. 1318]; German translation, Berlin, 1956. H. Deresiewicz, Italy

697. Chang, F.-V., Bending of the clamped edged anisotropic rectangular plates (in English), *Scientia Sinica* **7**, 7, 716–729, July 1958.

Paper presents the solution of named problem—within classical anisotropic plate theory (M. T. Huber)—by means of double sine series. Deflection w is postulated as $\Sigma\Sigma\, a_{mn} \sin \alpha_m x \cdot \sin \beta_n y$ and unknown bending moments along the edges as $\Sigma E_m \sin \alpha_m x$, $\Sigma F_n \sin \beta_n y$. Two loading cases are successively considered: (a) uniform q; (b) concentrated P at center.

By application of the principle of virtual displacements the relationship between a_{mn} and E_m, F_n is established. The boundary conditions at the edges yield then—as in the case of the isotropic clamped plate—a system of infinite simultaneous linear equations to solve for E_m, F_n. In addition the author indicates for some of the infinite series entering the calculations their limiting sum in closed form. He does this for the three cases $H^2 \gtrless D_x \cdot D_y$.

For the case $H^2 < D_x \cdot D_y$ the author carries the calculations further for a square plate under (a), and (b), with given numerical values of the elastic constants. Limiting his computations to 8 coefficients E_m, F_n, he solves for these, and indicates as "fairly good" the approximation he obtains for maximum bending moments at the edges.

Paper is an interesting complement to the works of M. T. Huber and S. G. Lekhnitski. G. H. Beguin, Switzerland

698. Suchar, M., General form of the surface of deflection of a thin anisotropic plate in a multiconnected region (in English), *Bull. Acad. Polonaise Sci. (IV)* **8**, 2, 69–76, 1960.

Author discusses the differential equation of deflection of the middle plane of an anisotropic plate

$$D_{11}\frac{\partial^4 w}{\partial x^4} + 4D_{16}\frac{\partial^4 w}{\partial x^3 \partial y} + 2(D_{12} + 2D_{66})\frac{\partial^4 w}{\partial x^2 \partial y^2} + 4D_{26}\frac{\partial^4 w}{\partial x \partial y^3} + D_{22}\frac{\partial^4 w}{\partial y^4} = q, \qquad [1]$$

where D_{ij} are the material constants and $q = q(x, y)$ denotes a load on the outer surface. Author considers an $(n + 1)$-connected region F, bounded by $(n + 1)$ Jordan's curves $C_1, C_2 \ldots, C_{n+1}$, the last of which includes all the remaining ones, these curves having no common points. The characteristic equation of [1] has the roots $\mu_1, \mu_2, \bar{\mu}_1, \bar{\mu}_2$. By transforming $z_1 = x + \mu_1 y$ one obtains the region F^*, the boundaries of which are constituted by the curves C_1^*, $C_2^*, \ldots, C_{n+1}^*$. The region F^{**} is obtained by transforming $z_2 = x + \mu_2 y$; its boundaries are constituted by $C_1^{**}, C_2^{**}, \ldots, C_{n+1}^{**}$. The general form of the function $w(x, y)$, continuous with its derivatives up to the fourth inclusively, satisfying in an $(n + 1)$-connected region the homogeneous equation [1] is given by

$$w(x, y) = Re\left\{\sum_{k=1}^{n} [a_k(z_1 - z_{1k})^2 + b_k(z_1 - z_{1k}) + c_k] \ln (z_1 - z_{1k}) + \sum_{k=1}^{n} [d_k(z_2 - z_{2k})^2 + e_k(z_2 - z_{2k}) + f_k] \ln (z_2 - z_{2k}) + \varphi(z_1) + \psi(z_2)\right\}, \qquad [2]$$

where $\varphi(z_1)$ and $\psi(z_2)$ denote holomorphic functions in the regions F^* and F^{**} respectively, while $z_{1k} = x_{1k} + \mu_1 y_{1k}$, $z_{2k} = x_{2k} + \mu_2 y_{2k}$ denote arbitrary fixed points inside the curves C_k^* and C_k^{**} respectively. The complex constants a_k, b_k, c_k, d_k, e_k and f_k may be determined from the conditions of single valuedness of the function $w(x, y)$ and its derivatives and from the conditions of equilibrium. The case in which the curve C_{n+1} tends to infinity is also considered. P. P. Teodorescu, Roumania

699. Woinowsky-Krieger, S., Bending of an infinite orthotropic plate on an elastic foundation (in German), *Ing.-Arch.* **29**, 1, 22–30, 1960.

The pressure between plate and foundation is calculated by means of admissible formulas. An influence function characterises the foundation. It changes with the hypothesis in respect to the elastic qualities of the foundation. Two assumptions are treated: the ground-figure theory and the elastic half-space. With these hypotheses author calculates the pressure on the foundation and the bending-moment and bending-sense of the plate under a single load. As examples for the plate are treated the steel-concrete-plate and the beam-support. L. Foppl, Germany

700. Allen, D. N. de G., and Severn, R. T., The stresses in foundation, Part 1, *Proc. Instn. Civ. Engrs.* **15**, 35–48, Jan. 1960.

Author examines plates on elastic foundation under concentrated loads; the soil reaction at any point is considered proportional to the deflection w at that point (Winkler). The Germain-Lagrange differential equation of the fourth order (w is the only unknown function) is divided into the two well-known equations of the second order [w and $M = -B(w_x'' + w_y'')$ are the unknown functions] and these are replaced by corresponding finite difference equations (Marcus's method). The equations system is then solved by iteration. The final results of two examples are given; other examples and developments are announced for a forthcoming part of the article. P. Pozzati, Italy

Buckling

(See also Revs. 654, 667, 682, 690)

701. Wnuk, M., and Zyczkowski, M., Influence of weakening of a bar on the critical force in the elastic-plastic range (in English), *Bull. Acad. Polonaise Sci. (IV)* **7**, 7/8, 447–457, 1959.

Authors examine the transcendental equation for the buckling load of a pin-ended stepped-column, the step being a small reduction in area over a short length in the middle of the column. An approximate equation for the tangent modulus in each region is used. A perturbation method is used to obtain an expression for the buckling load. An example is given which shows a larger decrease in the buckling load due to the elastic-plastic effect than due to the change in area alone. B. E. Gatewood, USA

702. Norris, C. B., Compressive buckling curves for flat sandwich panels with dissimilar facings, For. Prod. Lab., U. S. Dept. Agric. Rep. 1875, 12 pp., Sept. 1960.

In this report curves and formulas are presented for use in calculating the buckling of flat, simply supported panels of sandwich construction under edgewise compressive loads. The curves apply particularly to sandwich panels having one facing of glass-fabric laminate, the other facing of an isotropic material, and a honeycomb or isotropic core.

From author's summary

703. Miura, K., Thermal buckling of rectangular plates, Aero. Res. Inst., Tokyo University Rep. 353, 51–75, May 1960.

Author analyzes the thermal buckling of the plate simply supported by the web and subjected to an arbitrary symmetrical temperature distribution which is expressed by means of double sine series. Duhamel's analogy and the principle of virtual displacements are used. It is assummed that the edges can move but remain straight. The effects of the temperature and of the stiffness of the web are investigated.

The buckling criterion is established and a simple formula is obtained with reasonable accuracy for engineering purposes. Several diagrams are given and the solutions are compared with those of Hayashy, Klosner and Forray, who have treated the problem approximately. Author shows that their results are larger than his exact values, and either a decrease in the stiffness of the webs or an increase in the nonuniformity of temperature can result in a much larger discrepancy with the more accurate value.

S. Sarkadi Szabo, Hungary

704. Popov, S. M., Stability of circular plates beyond the elastic limit (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **27**, 92–100, 1960.

Equilibrium and compatibility equations for the purely plastic and elastic-plastic regions are solved. Satisfying the boundary conditions clamped or supported, continuity requirements and the condition of single-valuedness of the tangential displacement, author obtains three characteristic equations containing three unknowns: the critical compressive thrust, the coordinate of the common boundary and the function showing the variation of the plate thickness with radial distance within the plastic zone. The last is given by an independent second-order nonlinear differential equation. A function in this is approximated and transformation reduces it then to a Bessel equation. This makes the calculation of the critical thrust simpler. In absence of elastic-plastic zone, the characteristic equations are shown to reduce to elementary forms. G. A. Nariboli, India

705. Hamada, M., Compressive or shearing buckling load and fundamental frequency of a rhomboidal plate with all edges clamped, *Bull. JSME* **2**, 8, 520–526, Nov. 1959.

Title problems are solved by assuming the deflection is given by an infinite sum of trigonometric terms and then minimizing the potential energy subject to the appropriate constraints. Numerical results which are obtained by trial and error calculations are presented for the smallest buckling load and the fundamental frequency of plates with angles of skew equal to 75°, 60°, and 45°.

R. E. Beckett, USA

706. Prusakov, A. P., Improving the solutions of some problems in constructional mechanics by the application of the Kantorovich-Vlasov method aided by the iteration method (in Russian), *Sb. Nauchn. Prats'. Dnepropetrovsk. Inzh. Bud. In-ta* no. 3, 131–136, 1957; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 2940.

An investigation is carried out of the strength of a clamped rectangular plate compressed in one direction. The solution follows the Kantorovich-Vlasov method. The deflection function is presented in the form of the products of functions x and y, one of these having previously been given a value which will satisfy the boundary conditions on the parallel edges, while the other is sought from the differential equation obtained from the variational equation of the problem. Subsequently, at the second approximation the initially given function is improved, while for the "known" the only assumption made is that the found function should satisfy the boundary conditions on the other parallel edges. A comparison is made of the magnitude of the smallest values for the parameter of the critical load m_1, depending on the ratio of the sides of the plate, found in the first and second approximations of the method in use, with the magnitude m_t found by Taylor's method. It is shown that the second approximation gives good convergence with the solution carried out by Taylor's method.

V. F. Karavanov

Courtesy Referativnyi Zhurnal, USSR

707. Singer, J., The effect of axial constraint on the instability of thin circular cylindrical shells under external pressure, AFOSR TN 60–165 (Israel Inst. Techn., Dept. Aero. Engng. TN 1), 20 pp., Sept. 1959.

Author considers an approximate energy solution for the buckling of cylindrical shells observing the condition of elastic restraint in the direction of the generator of the shell. Two types of elastic constraints are assumed: (a) restraints active throughout the process of loading; (b) restraints active only during the process of buckling.

The Rayleigh-Ritz method of solution is applied and within the prescribed limitations it is apparent from the results pertaining to the buckling of cylindrical shells under hydrostatic or uniform lateral pressure that the critical pressure varies little between the proposed restraint conditions (a) and (b).

The solution contains the results of von Mises, Batdorf and others. This work, in its simplicity, clarity, and descriptive presentation, is written in the best tradition of engineering exposition.

G. A. Oravas, Canada

708. Ceradini, G., On the design of longitudinal web stiffeners, for plate girders in bending, and subjected to the danger of instability by buckling, Parts 1 and 2 (in Italian), *G. Gen. Civ.* **97**, 5, 357–374, May 1959; **97**, 6, 455–468, June 1959.

Paper consists of two parts. In first part, a method is presented, based on the idea of economical relative stiffness, to evaluate the influence of stiffeners against buckling, in structures reducible to a monodimensional scheme. After stating the basic case of a compressed and bent bar with one lateral elastic support, the case is contemplated of longitudinally stiffened webs in plate girders subjected to bending. Numerical example shows good agreement with other known methods. In second part, the influence of geometrical inaccuracies is considered by the same method, and two numerical examples are given showing close agreement with experimental results obtained by Prof. Massonet.

F. Correia de Araujo, Portugal

709. Gregory, M., The application of the Southwell plot on strains to problems of elastic instability of framed structures, where buckling of members in torsion and flexure occurs, *Austral. J. Appl. Sci.* **11,** 1, 49–64, Mar. 1960.

Stability of a triangular frame, when buckling out of its plane occurs, is solved analytically, considering equilibrium of bending moments and torques at joints expressed in terms of joint rotation. An extensive experimental investigation follows theoretical solution. Author shows the Southwell plot on strains to be linear in the tested cases. The critical force obtained from tests by means of the Southwell plot is in very good agreement with the theoretical solution. Author concludes the Southwell plot may be expected to be linear in other cases of three-dimensional buckling and that it furnishes a convenient method for experimental determination of the critical force. P. Wilde, Poland

710. Frisch-Fay, R., The buckling of struts with suddenly changing cross sections, *Civ. Engng. Lond.* **55,** 644, 363–367, Mar. 1960.

Paper considers elastic stability of axially-loaded, hinged-end struts whose cross section changes abruptly at one or two points. The two or three segments thus formed are arbitrary in length and have independent but constant values of EI. Ideal conditions are assumed: material is elastic, homogeneous and isotropic; member is initially straight; and load is applied with no eccentricity.

Analytical solution follows classical method [S. Timoshenko, "Theory of elastic stability," McGraw-Hill, 1936, p. 130] and extends solution to more complicated situation. Solution of second-order differential equation applied to segments results in set of homogeneous equations whose determinant must equal zero if solution is not trivial. Setting determinant equal to zero yields transcendental equation whose roots lead to eigenvalues of critical load. Lowest value of critical load is sought by trial-and-error solution of transcendental equation. For struts having one change in cross section (two segments), curves of solutions are given.

Author stresses that solutions obtained refer to ideal elements and cannot be used directly for design purposes. A method of adaptation is suggested. J. G. Hammer, USA

711. Przemieniecki, J. S., Struts with linearly varying axial loading, *Aero. Quart.* **11,** 1, 71–98, Feb. 1960.

Elastic prismatic struts with uniformly distributed axial loading are analyzed: (a) with loading applied along the undeformed and (b) along the deflected strut axis. The treatment (b) is known as classical whereas (a) may be often found in airplane structures. Lateral distributed loading, lateral and axial concentrated forces and couples are taken into account as well.

The problem is solved twice: by means of Bessel functions when concentrated axial force is zero at one end of the strut and by means of power series in the other case. The functions are analyzed and shown in diagrams. Final diagram shows critical loads for four types of end conditions in both treatments. Equations for deflections and bending moments, gathered in Appendix in eleven particular modes of support and loading, are very convenient for practical applications.

M. Zyczkowski, Poland

Vibrations of Solids

(See also Revs. 607, 615, 705, 751, 755, 776, 811, 1064, 1065, 1066, 1102)

712. Shkonev, Yu. S., Vibrations of extensible strings (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **27,** 81–86, 1960.

The problem of the vibration of a finite, homogeneous string is considered. One end of the string is fixed; to the other a force proportional to the deformation of the end is applied. The transverse flexure is also taken into account in the form of longitudinal deformation. The equation of motion is nonlinear and is solved using series developments. In particular, the solution for a perfectly flexible string is obtained by reducing the rigidity to zero. Natural and forced vibrations are examined.

N. E. Cristescu, Roumania

713. Kaliski, S., and Petykiewicz, J., Dynamical equations of motion and solving functions for elastic and inelastic anisotropic bodies in the magnetic field, Proceedings of Vibration Problems no. 2, 17–35, 1959.

The object of the paper is to present equations of motion for elastic and inelastic anisotropic conducting solids situated in a magnetic field. So called "solving functions" are introduced into the equations. They are a system of functions by means of which may be expressed the vector components of the individual fields, and which, when introduced into the basic set of equation, permits separation. That is, they allow the reduction of n conjugate partial differential equations to n independent partial differential equations for solving functions of an appropriately higher order.

R. L. Bisplinghoff, USA

714. Kobrinskii, A. E., Shlyakhtin, A. V., and Yamshchikova, M. N., Vibrations of nonlinear systems subject to periodic impulses (in Russian), *Trudi Inst. Masbinoved., Akad. Nauk SSSR* **28,** 70, 49–67, 1958.

Complicated working processes of several types of machines with periodical running (power hammers, etc.) can be best investigated by directly solving related dynamical problems. As a rule, substantial simplifications of this difficult question come from two favorable facts: the periodicity of working regime makes it possible to omit the transient processes and, secondly, we have here to do with shocks during vanishingly small times.

The value of the present paper lies in that it considers periodical impulses applied to systems with nonlinear elastic coupling. Thus the characteristic consists of two straight lines joined one to another at less than a given angle. The analysis is based on a suitable generalization of the method of boundary conditions. The merits of this procedure lie in considering not the initial but the boundary data which follow from the periodicity of motion and characterize the velocity of the system before and after the impact.

Considered are processes both with and without friction. Instructive diagrams raise the technical significance of this valuable paper. V. Vodicka, Czechoslovakia

715. Lyon, R. H., Response of a nonlinear string to random excitation, *J. Acoust. Soc. Amer.* **32,** 8, 953–960, Aug. 1960.

The response of a perfectly flexible string with longitudinal deformation to random excitation is studied in some detail. The equations of motion are essentially those of Carrier [*Quart. Appl. Math.* **3,** 157–165, 1945]. The modified mean-square response for the "elastic" string is discussed and it is shown that the mean square deflection is diminished from the linear case. From a study of the fourth moments it also appears that the shape of probability distributions of the transverse displacement are altered, the response to gaussian noise being in general nongaussian.

From author's summary

716. Mitra, A. K., A note on the torsional vibration of a conical bar with varying rigidity and density, *J. Technol., Calcutta* **4,** 1, 37–39, June 1959.

This short paper (3 pages) deals with torsional vibration of a conical bar with varying rigidity μ and density ρ (μ and ρ are assumed to be proportional to the distance r from the cone vertex: $\mu = \mu_0 r$, $\rho = \rho_0 r$, μ_0 and ρ_0 being constants).

Radial u_r and meridian u_θ components of deplacement are taken = 0.

Only one equation of motion is to be satisfied, which can be split into two equations, respectively, in r and in θ, the latter being satisfied by a spherical harmonic, the former by a Bessel function of $K r$ ($K^2 = \rho_0 p^2/\mu_0$; p = frequency/2π).

Boundary conditions (zero deplacement for a given $r = a$) determine values of Ka, i.e. of p for free vibration.

Reviewer believes this paper to be of mathematical rather than of technical interest, the possibilities of its technical use being very reduced by the assumed hypothesis ($\mu = \mu_0 r$; $\rho = \rho_0 r$).

R. Giovannozzi, Italy

717. Cheng, C.-M., and Ma, Z.-K., Vibration of cantilever beam placed against water with free surface (in Chinese), *Acta Mech. Sinica* **3**, 2, 111–119, Apr. 1959.

It is assumed that (1) the free surface of liquid coincides with the free end of the cantilever, (2) the displacement during vibration is everywhere small, and (3) the liquid is incompressible and nonviscous. The equation of motion is established relating the displacement and the change of liquid pressure at $x = 0$, the base line of the beam. This may be permissible when displacements are small. The pressure change is then obtained by hydrodynamical considerations resulting in an integral equation. The solution is first expressed in terms of normal functions. The ratio of the lowest frequencies (frequency with liquid to that without liquid) is subsequently checked by Rayleigh's method. The same ratio for a cantilever with linearly varying depth is also given. Finally, the evaluation of the influence of liquid on frequencies by means of perturbation of a small parameter is discussed.

Reviewer believes that the paper is useful in studying the dynamic response of a cantilever containing liquid of negligible viscosity. The treatment of the problem is comprehensive, although more pertinent references should be given. The subscript i is missing in the first expression on page 114.

D. H. Cheng, USA

718. Mathews, P. M., Vibrations of a beam on elastic foundation, Part II (in English), *ZAMM* **39**, 1/2, 13–19, Jan./Feb. 1959.

Problem of vibrations of an unlimited beam on elastic foundation has been once more [see AMR **12**(1959), Rev. 1787] considered by the author. This time a damping force, depending linearly on velocity, has been taken into account. Externally applied exciting force varies on $F_0 \cos \omega t$ and its point of application moves along the beam with constant velocity. Using Fourier transformation the solution has been given for two particular cases: (1) Alternating load at the origin; (2) a moving load of constant magnitude. Work reveals an interesting fact that in damped case the displacements of the beam are nonsymmetrical with respect to instantaneous point of application of the force, but they are greater behind than ahead of it. Author proves that the results considering point 2 become identical with ones following from J. T. Kenney's paper [*J. Appl. Mech.* Dec. 1954; AMR **8**(1955), Rev. 1286] for the "underdamped" and "overdamped" cases.

K. Piszczek, Poland

719. Stepanov, R. D., On some quadratures of fundamental beam functions (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **26**, 94–100, 1958.

Author defines five sets of characteristic functions which give the normal modes of vibration of a beam with ends clamped-clamped, free-free, clamped-free, clamped-hinged and hinged-free. For each type of support, except free-free, expressions are listed for the definite integral over the length of the beam of products of derivatives of the characteristic functions. These integrals arise in applying the Ritz method to vibration of rectangular plates as in Young, AMR **4**(1951), Rev. 1929, and were studied by author in connection with the flutter of plates and membranes in a supersonic flow of gas. Tables of the integrals are given which extend, and presumably correct, part of those in Young's paper.

E. W. Bowen, Australia

720. Mazurkiewicz, Z., Free vibration of an isotropic non-homogeneous rectangular plate (in English), *Bull. Acad. Polonaise Sci. (IV)* **8**, 2, 63–68, 1960.

Mathematical development of method for determining vibration frequencies of a rectangular plate, simply supported along its periphery, is presented. Density and flexural rigidity are assumed to be known functions of x and y. Differential equation of the plate is replaced by a homogeneous Fredholm integral equation, which is in turn reduced to an infinite system of homogeneous linear equations. Emphasis of paper is on mathematical development rather than engineering application.

J. C. Truman, USA

721. Mazurkiewicz, Z., General expressions for the boundary conditions and the differential equation of equilibrium and vibration of an anisotropic, non-homogeneous plate (in English), *Bull. Acad. Polonaise Sci. (IV)* **7**, 9, 519–530, 1959.

Hamilton's principle is used to derive the boundary conditions and the field equations for an anisotropic nonhomogeneous plate, in which both the densities and rigidities are variable. No particular problems are discussed.

B. R. Seth, India

722. Moseley, D. S., Contribution to the theory of radial extensional vibrations in thin disks, *J. Acoust. Soc. Amer.* **32**, 8, 991–995, Aug. 1960.

The theory of the radial mode of isotropic disks of vanishing thickness is extended to the case of small thickness-to-diameter ratio. Resembling the Rayleigh and Pochhammer-Chree correction to the longitudinal modes of a thin circular bar, the radial mode correction by Pochhammer-Chree method is shown to be

$$[1 - \tfrac{1}{6}[R_i \nu b/(1 - \nu) 2a]^2],$$

where R_i are the roots of zero thickness disk theory, ν is Poisson's ratio, and $b/2a$ is the thickness-to-diameter ratio. Test of this and of a radial mode correction by Rayleigh's energy method has been made with the aid of frequency measurements on weakly prepolarized barium titanate ceramic disks whose $b/2a$ ratios ranged from 0.0276 to 0.1171.

From author's summary

723. Yu, Y.-Y., Simplified vibration analysis of elastic sandwich plates, AFOSR TN 59-1082 (Polyt. Inst. Brooklyn, Dept. Mech. Engng. TN 5), 24 pp., Aug. 1959.

The results of three earlier papers [AMR **13**(1960), Revs. 2237, 2799, and 2878] have been simplified for low frequency ranges and/or plates with very thin faces. The accuracy of these equations is determined by comparing frequency results for infinite plates treated by the simplified equations and the more exact theory of the earlier papers.

A. H. Hausrath, USA

724. Gottenberg, W. G., Experimental study of the vibrations of a circular cylindrical shell, *J. Acoust. Soc. Amer.* **32**, 8, 1002–1006, Aug. 1960.

An apparatus is described which permits the mode shape of a vibrating circular cylindrical shell to be obtained quite easily. These measurements are made without contacting the cylinder and can be converted to actual linear values. A representative number of results obtained with such a system are shown to illustrate the relationship between the nodal pattern and frequency in a cylinder as well as the effect of internal pressure on these frequencies. Finally, comparisons are made between these results and Timoshenko theory and an appropriate shell theory.

From author's summary

725, Greenspon, J. E., Axially symmetric vibrations of a thick cylindrical shell in an acoustic medium, *J. Acoust. Soc. Amer.* **32**, 8, 1017–1025, Aug. 1960.

This paper treats the dynamic behavior of infinitely long thick cylindrical shells surrounded by water. The shell is excited by

axially symmetric forces. The solution is formed by coupling the three-dimensional elastic solution with the expression for the fluid pressure in cylindrical coordinates. Curves are presented which give the forced vibration amplitude and acoustic pressure in the water as a function of frequency for various modes of vibration of the cylinder. From author's summary

726. Ellington, J. P., and McCallion, H., Blade frequency of turbines—effect of disc elasticity, *Engineering* **187,** 4862, 645–646, May 1959.

Authors use cantilever beams radiating from a uniform elastic ring as mathematical model of turbine blades attached to the turbine disk. The uniform elastic ring is not permitted to deflect radially at the points where the beams are attached. Calculations show that frequency spectrum consists of an infinite number of bands which are centered close to those of the cantilever. Authors indicate these results suggest an explanation for the scatter found in vibration tests. J. W. Mar, USA

727. Volkov, A. N., Vibration of a cylindrical shell in the stream of an ideal fluid (in Czech), *Aplik. Mat., Ceskoslov. Akad., VED* **3,** 3, 161–169, 1958.

The dynamic behavior of a cylindrical shell is examined. The presence of an ideal fluid is characterized by its apparent mass, and the influence of the stream velocity on the shell's dynamic response is examined. Analytic expressions are derived for the frequency in terms of characteristic parameters such as flexural rigidity, number of half sine waves, fluid density, cylinder length. H. H. Hilton, USA

728. Burmistrov, E. F., Nonlinear transverse vibrations of orthotropic shells of revolution (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **26,** 5–20, 1958.

Paper presents valuable extension of Grigoliuk's work on this subject. The elastic properties of the shell are assumed to be cylindrical orthotropic. Author investigates nonlinear free and forced vibration of the spherical and conical shell under various end conditions. The exciting forces are composed of uniform normal pressure and centrally acting concentrated force of the same frequency.

The deformation is approximately described by use of polynomial expression, which fulfills the boundary conditions. The Galerkin-Bubnov method is then applied to determine the approximate eigenfrequency and amplitude of vibration. The given theory is demonstrated on the example of vibration of corrugated plates which can be treated as elastically orthotropic. Paper does not present any experimental data; the accuracy of obtained results is not discussed. K. Julis, Czechoslovakia

729. Elpat'evskii, A. N., Free vibrations of prismatic shells of the caisson type occuring in airplane wings (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **26,** 78–84, 1958.

Assuming that the airplane wing is a cantilever prismatic shell of constant cross section with nondeformable contour, the unknown generalized displacements are obtained by means of Vlasov's variational equations, coefficients of which can be determined by quadratures. The system of partial differential equations of forced vibrations of a shell is deduced. In the case when the external loads vanish the above system of equations governs the free vibrations of a shell. Further, one treats only the case of the free vibrations assuming the generalized displacements as harmonic functions. Hence the system of the partial differential equations reduces to the system of usual differential equations. The problem of the determination of the forms and the frequencies of the vibrations reduces to the problem of the determination of the eigenfunctions and the eigenvalues of this set of equations.

D. Raskovic, Yugoslavia

730. Kolousek, V., Vibrations of bridges with continuous main girders (in English), *Publ. Int. Assn. Bridge Struct. Engng.* **19,** 111–132, 1959.

"Paper gives theoretical and experimental analysis of the dynamical effects of a two-cylinder locomotive with unbalanced driving axles crossing a bridge continuous over three spans." (From author's summary).

Measured and calculated results, carried out according to author's earlier study [AMR **9**(1956), Rev. 85], are shown to be in good agreement.

E. P. Villarreal, Argentina

731. Gauzy, H., and Pironneau, Y., Can an airplane have two identical frequency vibrations? (in French), *Recb Aëro.* no. 64, 43–48, May–June 1958.

This paper examines the conditions that must be satisfied by the coefficients of inertia and rigidity of a system in order that two of its natural frequencies should be equal. The analysis leads to certain conditions and corollaries of practical importance. These conditions are applied to possible aeronautical structures and the conclusion is reached that it is possible for certain airplane structures to have two equal natural frequencies. The analysis is quite ingenious and is carried out in the notation of matrix algebra.

L. A. Pipes, USA

732. Pidd, G. S., The tuned damper and its vector diagram, *Engineer, Lond.* **210,** 5462, 531–532, Sept. 1960.

The described vector method deals with viscous torsional vibration dampers which are tuned by means of an elastic connection. Into this category can be placed rubber dampers and steel spring dampers running in oil, although if the spring stiffness varies with amplitude, its most unfavorable value should be investigated.

From author's summary

733. Andrews, G. J., Vibration isolation of a rigid body on resilient supports, *J. Acoust. Soc. Amer.* **32,** 8, 995–1001, Aug. 1960.

The equations of motion of a rigid body supported by an arbitrary number of arbitrarily oriented and located resilient mounts with damping are developed with rigor. Their solution is given in a form suitable for high-speed electonic digital computer programing and includes prediction of natural frequencies, static displacements and load distribution to the mounts due to static loading, and frequency response curves for a given isolation system. An appendix is also included for transforming the inertial properties of a rigid body to a desired frame of reference.

From author's summary

734. Toriumi, I., Interferences in vibration between two foundations, *Technol. Rep. Osaka Univ.* **10,** 113–117, Jan. 1960.

Paper deals theoretically with the interferences in vibration between two foundations which are located near each other on the surface of semi-infinite elastic medium.

From author's summary

735. Merkulov, L. G., and Kharitonov, A. V., Theory and analysis of sectional concentrators, *Soviet Phys.-Acoustics* **5,** 2, 183–190, Nov. 1959. (Translation of *Akust. Zb., USSR* **5,** 2, 183–190, Apr./June 1959 by Amer. Inst. Phys., New York, N.Y.)

Sectional ultrasonic concentrators, made from rods of variable and constant cross section, are considered in the paper. Expressions for the resonance conditions, the amplification, and input impedance are obtained in general form. Special cases of practical importance are analyzed numerically and the optimum shapes for concentrators are determined. Characteristics for the input impedance of various concentrators near resonance are constructed. Some of the results of experimental investigations are quoted.

J. S. Arnold, USA

736. Kul'mach, P. P., Rigidity of foundations for massive hydraulic structures (in Russian), *Gidrotekh. Stroit.* **27**, 4, 35–38, Apr. 1958.

The coefficients of rigidity appearing in the expressions for the free and forced oscillations of structures lying on elastic ground have been calculated by the author from the oscillations and pressures produced by waves on a quay in Algiers and measured after the destruction of one part of the quay [J. M. Renaud, 1935]. Two groups of data led to approximately the same results, and the values estimated from the less complete data for a quay in Genoa are of the same order of magnitude. As the accelerations of such structures are very small, the coefficients of rigidity are not considerably influenced by the presence of water.

The observations on the two quays mentioned and some others show that the quays start to oscillate at low waves.

L. Suklje, Yugoslavia

737. Datta, S. K., Note on forced torsional vibration of a viscoelastic circular cylinder, *Bull. Calcutta Math. Soc.* **51**, 4, 167–170, Dec. 1959.

Some types of forced torsional vibrations of a circular cylinder of viscoelastic material have been considered by Thompson (1933). Author uses the stress-strain relations similar to those assumed by him and solves a more complicated type of problem.

From author's summary

Wave Motion and Impact in Solids

(See also Revs. 658, 713, 1100, 1102, 1125)

738. Miles, J. W., Homogeneous solutions in elastic wave propagation, *Quart. Appl. Math.* **18**, 1, 37–59, Apr. 1960.

Author considers for elastic isotropic medium those displacements specified by three functions which satisfy two-dimensional wave equation. Under suitable boundary conditions, each function is assumed homogeneous of degree zero in polar coordinates r, θ and time t and hence function of two variables θ and t/r. By Chaplygin transformation, this function then satisfies either the Laplace or the wave equation (depending on elliptic or hyperbolic nature). Solutions are obtained by complex variable and characteristics theory. Author points out class of problems in which simple wave zones occur in hyperbolic domain allowing solutions to be continued into elliptic domain without explicitly specifying conditions on common boundary.

Author applies technique developed to obtain complete solution for diffraction of P and SV waves by a traction-free half plane.

C. N. de Silva, USA

739. Chakraborty, S. K., On compressional waves in the direction of the axis of a cylindrical hole in an anisotropic medium having hexagonal symmetry, *Bull. Calcutta Math. Soc.* **51**, 4, 142–144, Dec. 1959.

740. Buchwald, V. T., Elastic waves in anisotropic media, *Proc. Roy. Soc. Lond.* (*A*) **253**, 1275, 563–580, Dec. 1959.

The author applies Lighthill's recent method for the asymptotic evaluation of Fourier integrals [*Phil. Trans. Roy. Soc. Lond.* (*A*) **252**, 397–430, 1960] to the calculation of displacements of points far from a radiating point source in an infinite, anisotropic medium. He finds that special directions can exist for which the amplitude decays more slowly than inversely with the radius. Special emphasis is given to the case of transverse isotropy, and a specific example for harmonic radiation in such a medium is discussed.

J. W. Miles, USA

741. Shkenev, Yu. S., Deformation of free cylindrical shells subject to impulses (in Russian), *Inzhener. Sbornik Akad. Nauk SSSR* **26**, 54–58, 1958.

Author assumes the shell of cylindrical form to be elastically isotropic and freely located in space. The loading impulse is supposed to be uniformly distributed along the meridian line of the shell. According to these assumptions the problem of deformation after impact can be treated as two-dimensional and the Kirchhof theory of curved slender beam can be applied.

Nonlinear equation of motion is solved by the Galerkin method with a trigonometric approximation of the deflection.

The investigation was carried out for the case of arbitrary relation between loading forces and time.

Paper contains one numerical example, is well written and, for graduate engineers, easy to follow.

K. Julis, Czechoslovakia

742. Perzyna, P., Stress waves in a homogeneous elastic-viscoplastic medium (in English), *Arch. Mech. Stos.* **11**, 4, 441–473, 1959.

Author considers a medium whose behavior can be represented by a model of two dashpots, one spring, and one ideally plastic body; these are connected to give a Maxwell body in series with a Bingham body. He solves the wave propagation problem by the method of characteristics, both for spherical waves and for cylindrical waves. The mathematical work is heavy and is presented in considerable detail. Two numerical examples are given for spherical waves, the constants of the material being chosen as applicable to steel and to copper respectively.

F. C. Roesler, England

Soil Mechanics: Fundamental

(See also Revs. 747, 748, 751, 792, 819)

743. Mel'nikov, E. A., and Trumbachev, V. F., Stress distribution in pillars with elastic-plastic interlayers (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Metallurgiya i Toplivo* no. 4, 165–173, 1959.

In chamber-mining an important economical question is the necessary width of the pillars between the chambers. Most rock materials consist of various layers with different mechanical properties and cohesion between adjacent layers. Paper deals with the stress distribution in the pillars due to elastic-plastic interlayers in the pillar proper. Investigations are performed on models of a gelatinous material, embedded between two parallel glass-plates by the aid of photoelastic techniques. Two compositions with different mechanical properties are used to imitate the effect of an elastic-plastic interlayer. For pillar height-width ratios of 0.5 and 2 the influence of such a layer at the top, bottom and in the middle of the pillar is investigated with and without cohesion between the basic material and the interlayer in comparison with a homogeneous pillar. Experimental techniques and results are fully described and discussed.

R. G. Boiten, Holland

744. Butovskaya, V. A., The applicability to clay soils of the hypothesis of the invariability of the volume in plastic deformation (in Russian), Trudi N.-i. Osnovanii i Podzemn Sooruzh., Akad. Str-va i Arkhitekt. SSSR no. 33, 70–76, 1958; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 3077.

A study of the volumetric deformability of a clay was carried out by the method of compressing cylindrical samples with moisture contents of 58%. The initial volume of the sample was determined by the measurements of a test borer; the final volume was measured by means of the hydrostatic method or was calculated from the results of measurements of its dimensions in the deformed state. It was shown that at relative deformations of compression up to 0.85 the change in volume of the sample is not large and does not exceed 3.9%.

N. I. Malinin

Courtesy Referativnyi Zhurnal, USSR

745. Meschyan, S. R., An experimental investigation of the relations between the stresses and deformations of the creep in cohesive soils (in Russian), *Dokladi Akad. Nauk ArmSSR* **24,** 2, 61–66, 1957; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 3078.

Results are given for the determination of the character of compression over a period of time for two varieties of loam and a single variety of dust-like clay of broken structure, produced in compression plant with different compression loads. The samples were 1 cm high with a diameter of 7 cm. The majority of the samples were completely saturated with water. The tests were carried out two-by-two for eight of the twin samples with loads of 0.25, 0.5, 1 and 2 Kg/cm². It was found that compression of solid with broken-up structure, and in the absence of lateral expansion, with loads of from 0.25 to 2 Kg/cm² conforms with the linear theory of creep. An equation is given for the experimentally obtained stress function. It should be mentioned that in the analysis carried out of the results of the tests of cohesive soils there was no attempt made to separate out for analysis the compacting over a period of time which is dependent on the permeability of the soil (filtrational) and the compacting which is conditioned by the creep of the frame-work of the soil. Consequently the obtained stress function does not truly represent the skeleton of the soils. In some of the samples of the soils a sudden compacting was due to occluded gases in the soil, as the degree of saturation in these samples was less than 1.

S. A. Roza

Courtesy Referativnyi Zhurnal, USSR

746. Komul'skii, V. V., Calculation of seepage around curtains, considering their permeability (in Russian), *Gidrotekh. Stroit.* **27,** 4, 31–34, Apr. 1958.

The seepage flow can be found by the equation $Q = kH : \Sigma\phi$, where k is the coefficient of permeability of the subsoil, H the difference between the upstream and downstream hydraulic potential heights, and ϕ the so-called shape coefficients of the single underground fragments. Assuming the validity of the superposition and based on the previous investigations of the authors cited in the paper, the writer develops the equation for the shape coefficient of the incomplete, hanging curtain as a function of the permeability $k_0 = \eta k$ of the curtain, of its width δ and height S as well as of the whole permeable subsoil depth T and of the length L of the dam upstream and downstream, respectively, of the curtain. The influence of the contraction of the flow lines is represented by the coefficient ξ, the value of which can be found as a function of the ratios L/T and S/T from the diagrams given in the paper. The determination of the analogous shape coefficient appearing in the equation for the calculation of the hydraulic pressure at the downstream edge of the curtain is also dealt with in the paper.

L. Suklje, Yugoslavia

Soil Mechanics: Applied

(See also Revs. 700, 736, 746)

747. Fedorov, I. V., Certain problems in the elasto-plastic distribution of stresses in soils, associated with the analyses of foundations (in Russian), *Inzhener. Sbornik Akad. Nauk SSSR* **26,** 205–215, 1958.

Paper deals with the two-dimensional problem of the stress distribution in a cohesive weightless soil mass, limited by a slope and a horizontal plane, subjected to uniform distributed loads "p" (on the horizontal plane) and "q" (on the slope). According to elasticity criteria, a straight line limiting the plastic state in the mass when the difference "p – q" increases is determined. For greater values of this difference, the mass is divided into three parts: the two lateral parts in which an elastic distribution is assumed and a central one where plastic conditions are reached. Using Sokolovsky's plasticity analysis, author solves a system comprising equilibrium equations and limit equations between the elastic and plastic sectors. As a supplementary condition, a linear relationship between the slopes of the lines limiting the plastic sector is supposed.

Indications are given for using formulas deduced by the author, which take into account the values of the load "q," of the slope angle, and of the friction angle of the soil.

R.-J. L. Bally, Roumania

748. Fischer, K., Settlement of a circular surface with uniform load resting on a layered foundation (in German), *Beton u. Stahlbeton.* **54,** 12, 293–296, Dec. 1959.

Paper deals with the settlement due to a uniformly loaded flexible circular plate resting on the surface of a semiinfinite elastic horizontally layered soil. Author starts from the Boussinesq expression for the vertical displacements due to a point load acting on the surface of a homogeneous isotropic elastic semiinfinite solid. From this expression he obtains by integration the settlement of the center and of the contour points of the flexible circular area acted upon by a uniform load.

The settlement in the case of a layered soil, each layer being affected by a different value of the modulus of elasticity E, is computed by adding the values obtained for each single layer.

The results are presented in tables and graphs. Computations are worked out for an actual case.

R. Jappelli, Italy

749. Minnich, H., Theory of systems built into the ground (in German), *Bauingenieur* **35,** 5, 170–172, May 1960.

Author considers behavior of walls embedded in soil, but unfortunately his assumptions about soil reactions are highly unreal. He appears to be unaware of Rowe's extensive work in this field, which emphasizes the importance of pile flexibility and the compressibility of cohesionless soils.

T. K. Chaplin, England

750. Nagarajan, R., and Sundararaman, R., Settlement of structural foundations, *J. Instn. Engrs., India* **40,** 9 (Part 1), 539–555, May 1960.

All important structures need to be designed for settlement considerations besides bearing capacity. The limiting conditions of settlement depend not only on the type of structure but also on the conditions of the foundation.

In the case of clayey soils, the consolidation test gives a reliable estimate of the probable settlement only; however, in the case of cohesionless soils, attempt has been made to arrive at the probable settlement from the plate loading test, which is commonly used to assess the safe bearing capacity of the foundation soil.

There are various methods of controlling settlement in structures, and among these, the mechanical and automatic methods have shown promise, especially in the case of large framed structures on clayey soils.

The paper summarizes the up-to-date information in this field and includes recent studies made in India.

From authors' summary

751. Richart, F. E., Jr., Foundation vibrations, *Proc. Amer. Soc. Civ. Engrs.* **86,** SM 4 (*J. Soil Mech. Foundations Div.*), 1–34, Aug. 1960.

This paper is highly valuable to engineers although it presents no new theory. Diagrams are prepared from existing theoretical solutions for evaluating frequency and amplitude for rigid circular base oscillator resting on elastic semi-infinite body. Cases solved are (a) oscillator producing vertical exciting force; (b) oscillator producing horizontal exciting force; and (c) oscillator producing rocking moment. The forces may have amplitude which remains constant at all frequences (ω) or amplitude which is proportional to ω^2. The rocking moments considered have constant amplitudes with respect to frequency. Typical values of shear modulus and Poisson's ratio necessary for the evaluation of dynamic

characteristics of a foundation are given and methods of establishing them at a particular site are described. Two examples are included to show details of application of the theoretical methods. A diagram is also included which illustrates the possibility of stiffening the foundation by the use of point bearing piles.

K.-H. Chu, USA

Processing of Metals and Other Materials

(See also Revs. 624, 664, 777, 934)

752. Krivoukhov, V. A., and Belousov, A. I., Determination of the cutting forces on the basis of the physical characteristics of the metals being worked (in Russian). Investigations on the physics of the solid body (Issled. po Fiz. Tverdogo Tela), Moscow, Akad. Nauk SSSR, 1957, 132–138; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 3035.

Starting from the concept of cutting as a process of plastic compression, authors derive a semiempirical equation for the cutting forces, taking into account a number of physical properties of the metals being worked (heat capacity, melting point temperature, heat conductivity, and so forth).

G. S. Shapiro

Courtesy Referativnyi Zhurnal, USSR

753. Okushima, K., Hoshi, T., and Fujinawa, T., On the behavior of chip in steel cutting: Part 2, In the case of parallel type chip breaker, *Bull. JSME* **10,** 3, 199–205, May 1960.

This paper describes the behavior of the chip in steel cutting by the lathe tool with the parallel-type chip breaker, which is the most fundamental type of chip breaker.

The first half describes the curling radius of the chip bent by the chip breaker. Authors present a new equation about the curling radius. The latter half describes chip breaking by the chip breaker. Using the above equation of the curling radius, authors succeeded in an equational representation of the conditions in which the chip is properly broken. On the basis of this equational representation, a chart was drawn up for the design of the chip breaker.

From authors' summary

754. Leyman, R. E., The use of explosives in the working of metals, *So. African Mech. Engr.* **9,** 11, 273–291, June 1960.

Specially-developed explosives correctly chosen and properly handled are capable of performing certain working operations not otherwise feasible or economic. Hard-to-work metals can be formed into complex shapes at great speed and austenitic manganese steel castings can be "shock-hardened" effectively to inch depths. The processes are not suitable for mass production and must be judiciously applied and used with care.

Shock-hardening may prove applicable to castings in other metals whose mechanical properties are improved by cold working.

From author's summary

755. Rose, H. E., On the performance of high-duty vibration mills, *Trans. Inst. Chem. Engrs.* **38,** 3, 107–124, 1960.

In this paper an expression for the size of the out-of-balance weights necessary to maintain a vibration mill in motion is deduced. Expressions for the power absorbed in the charge of a mill, the power associated with the formation of new surface, and the power dissipated in friction in the bearings are also produced and from these expressions the variations in the mill efficiency arising from variations in the conditions of operation and in the size of the mill are studied.

This analysis shows that very high rates of grinding can be obtained by running the mills at high speed but that, under these conditions, the power dissipated in the bearings of a mill of conventional type is excessive and that as well as giving rise to mechanical difficulties the efficiency of the machine is seriously reduced.

It is also shown that these difficulties could well place an upper limit upon the size of a machine of this type. It is, however, suggested that these difficulties can be overcome by arranging that there is almost resonance between the vibration of the mill body and the rotation of the out-of-balance weight shaft and that under this condition mills of large size and of high efficiency are possible.

Some factors relating to the design of mills operating under these conditions are also discussed.

From author's summary

Fracture (Including Fatigue)

(See also Revs. 776, 777, 797, 814, 829, 1052)

Book—756. Symposium on basic mechanisms of fatigue (Presented at the 61st Annual Meeting of the American Society for Testing Materials, Boston, Mass., June 23, 1958), Philadelphia, Pa., American Society for Testing Materials, 1959, v + 121 pp. $3.75.

This little book contains the Chairman's introduction by T. J. Dolan and the text and discussion of six lectures. The first, by R. E. Keith and J. J. Gilman, describes studies on lithium fluoride, in which the movement of individual dislocations can be followed by an etching technique, and the conditions under which reversed straining leads to the multiplication of dislocations are determined with precision. The second, by P. J. E. Forsyth, discusses the slip lines, intrusions and extrusions formed during the fatigue of silver chloride, and observations of dislocations by allowing silver to print out on them. W. P. Mason describes tests on copper, silver and germanium at 17,400 cps, which disclosed an unexpected increase in elastic modulus on applying a static load. The results are explained by a dislocation model in which the long dislocations responsible for anelastic effects are held up by dislocations on other glide planes. The next paper, by M. R. Hempel, represents more classical metallurgy, and reports a detailed study of slip lines and fatigue cracks in single crystals of alpha iron and in polycrystalline aluminum. J. D. Morrow and G. M. Sinclair describe the relaxation at constant mean strain of externally applied stress under conditions of fatigue, and discuss the bearing of their results on the relaxation of internal stresses during fatigue. Finally, W. A. Wood presents and discusses some fine taper sections showing slip bands, cracks and surface markings in fatigued copper and brass.

The papers cover a wide field and are not closely related, but each in itself is a new study by ackowledged experts.

F. R. N. Nabarro, England

757. Danilov, Yu. S., and Kadobnova, N. V., Part played by the frequency of loading in fatigue tests, *Indust. Lab.* **25,** 6, 757–761, June 1960. (Translation of *Zavod. Lab., USSR* **25,** 6, 727–730, June 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

The strength of metals under cyclic load depends not only on the size and time of application of this load but also on its frequency. When the frequency of load application is reduced from 4750 cpm to 7.6 cpm, i.e., to 1/630, the duration of tests for all investigated materials increases 100–500 times, while the life measured in cycles decreases 1.5–5 times.

When the stress level is increased from 0.4 to 0.8 σ_B, the time to rupture $\tau_{7.6}/\tau_{4750}$ increases when the testing frequency is increased from 200 (at $\sigma_{max} = 0.4\ \sigma_B$) to 450 (at $\sigma_{max} = 0.8\ \sigma_B$); at the same time the difference in fatigue strength measured in numbers of cycles $N_{7.6}/N_{4750}$ changes from 0.19 (at $\sigma_{max} = 0.4\ \sigma_B$) to 0.72 (at $\sigma_{max} = 0.8\ \sigma_B$). With a reduction of frequencies the values of limiting endurance limits decrease and on the basis $N = 30000$

cycles they are about 90% when the frequency is reduced from 4750 to 7.6 cpm.

The sizes of zones of fatigue rupture are not dependent on the frequency of load application, and for the same loads the areas are nearly equal. With the decreasing frequency of loading and the working stress remaining the same the fatigue zone of the rupture becomes more polished. From authors' summary

758. Vsevolodov, G. N., Spreading of fatigue cracks in specimens of shipbuilding steel, *Indust. Lab.* **25,** 6, 765–766, June 1960. (Translation of *Zavod. Lab., USSR* **25,** 6, 734–735, June 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

In order to obtain experimental data on the rate of propagation of fatigue cracks, produced by bending stresses with changing sign, in specimens with various types of stress concentrators and of different sizes, author investigated the following steels: carbon steel plate 40 mm thick and low-alloy steel plate 32 mm thick. The mechanical characteristics of these steels are as follows: for carbon steel σ_S = 19 kg/mm², σ_B = 39 kg/mm², S_K = 73 kg/mm², δ = 30%, = 61% and H_B = 120 kg/mm² and for low-alloy steel 70 kg/mm², 75 kg/mm², 132 kg/mm², 15%, 62% and 179 kg/mm², respectively. From author's summary

759. de Fouquet, J., Contribution to the study of high temperature fatigue in steel (in French), *Rev. Mètall.* **55,** 12, 1133–1144, Dec. 1958.

Author studies the influence of temperature on the behavior of 0.05% carbon steel and Armco iron under repeated alternating cycles of constant strain amplitude; endurance limits are not determined. Main interesting conclusions are: (1) Up to 400°C the direction of slip bands within the grains are more influenced by the direction of macroscopic maximum shear stress than by the orientation of the grain; (2) from 400°C to 700°C polygonization occurs and deformation is more evident near grain boundaries where rupture finally occurs by slip; (3) at 700°C there is recrystallization by grain boundary movement or nucleation at grain boundaries; (4) an equicohesive temperature can be defined in fatigue, which for material studied (0.05% carbon steel) is between 450°C and 500°C. I. A. Cintra, Brazil

760. Frost, N. E., Notch effects and the critical alternating stress required to propagate a crack in an aluminium alloy subject to fatigue loading, *J. Mech. Engng. Sci.* **2,** 2, 109–119, June 1960.

Fatigue tests at zero mean load have been carried out on aluminum alloy (BS.L65) specimens containing edge cracks of various lengths. It was found that the relationship between the crack length l (inches) and the critical alternating propagation stress σ(ton/in.²) was given by $\sigma^2 l = 0.2$. A similar type of relationship (i.e., $\sigma^2 l = 5.5$) was obtained previously for mild steel.

Fatigue tests have also been carried out on notched specimens and the occurrence of non-propagating cracks discussed in terms of the above relationship.

From author's summary

761. Uzhik, G. V., Composite beams (or rods) as a means of raising load capacity and preventing brittle fracture at positions of concentrated stress, *Soviet Phys.-Doklady* **4,** 3, 571–573, Dec. 1959. (Translation of *Dokladi Akad. Nauk SSSR (N. S.)* **126,** 1, 41–43, May/June 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Paper presents limited experimental data for notched beams in simple bending to support the contention that beams whose cross sections are composite with respect to their width are less susceptible to brittle fracture than homogeneous beams. Phenomenon is associated with the observation that an increase in thickness of a plate with cutout must be accompanied by a transition from a predominantly plane stress to a predominantly three-dimensional nonhomogeneous strain state. K. S. Pister, USA

762. Rimrott, F. P. J., Mills, E. J., and Marin, J., Prediction of creep failure time for pressure vessels, *ASME Trans.* **82** E (*J. Appl. Mech.*), 2, 303–308, June 1960.

Authors derive expressions, based on large strain theory, for predicting the creep-failure time for thin-, thick-, and very thick-walled cylindrical vessels of circular cross section (with closed ends) subjected to internal pressure. Various simplifying assumptions are made to permit an analytical treatment of the problem. Results are presented in the form of equations, and graphs for easy determination of creep-failure time of pressure vessels, for a range in radius-to-wall-thickness ratios and materials parameters. Information should be of benefit to pressure vessel designers. However, an examination of the possible errors introduced in making the various simplifying assumptions, via comparisons with measured data, would appear to have been most desirable.

M. M. Lemcoe, USA

763. Elagin, V. I. and E'khina, E. V., Determination of the tendency of Al-Mg alloys to stress corrosion from the microstructure, *Indust. Lab.* **25,** 6, 733–735, June 1960. (Translation of *Zavod. Lab., USSR* **25,** 6, 703–704, June 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

The tendency of Al–Mg alloys with a high Mg content to stress corrosion depends on the type of structure, viz. the presence of almost continuous rings of the β-phase (or an intermediate chemical compound) along the grain boundaries.

In the present work authors have studied the tendency of AMg6T alloy to corrosion cracking depending on the type of microstructure after the thermal treatment. During the investigations, the degree of the decomposition of the solid solution and the distribution of the decomposition products in the grains of the solid solution were studied. From authors' summary

764. Brennert, S., Stress corrosion in stainless steels.—Effect of potential difference between liquid and metal, *Jernkontorets Ann.* **144,** 7, 560–566, 1960.

Experimental Stress Analysis

(See Revs. 662, 709, 743, 796)

Material Test Techniques

(See also Revs. 756, 912, 975, 1001)

765. Buckle, H., The microhardness test and its application (in French), Publ. Scient. Tech. Min. Air, France N. T. 90, 274 pp., 1960.

Though the physical meaning of hardness is far from being really understood, the hardness test has found a wide use in science and industry because of its simple and quick performance. With usual technique, often small loads were applied to obtain a "microhardness," which was expected to give the individual properties of the area under test. But soon it was found that these results showed a wide scatter though the test conditions seemed to be the same in each case. From these facts resulted the necessity of investigating the special conditions of the microhardness test. For reliable interpretation of results, it was also necessary to properly define microhardness. The author, a recognized specialist, tries to clarify these problems in his paper. This is done in a convincing manner, based on a rich experience and covered by many examples. The representation is clear and profound. For these reasons this outstanding paper is of great interest for all people working in this field. It can also give much stimulation to

all investigators of the microstructure of matter, as the test may, in addition to other methods, provide useful information.

Author proposes as the range of Vickers microhardness that range of load (5 g to 50 g, extreme limits 1 g and 200 g) and indentation diameters (3 μ to 50 μ) in which characteristic anomalies relative to macrohardness range appear, such as load dependence of hardness number and high sensitivity of results to special conditions of specimen preparation, testing method and measuring of indentation. These anomalies are characteristic for this range. They cease as a decisive factor in the load range from 200 g to 1 kg or indentation diameters from 50 μ to 300 μ (called test of reduced load), and cease definitely in the macrohardness range of higher loads. Author points out that useful results can only be obtained if microhardness tests are conducted with proper testing apparatus and by specially trained personnel. Tests done with usual macrohardness apparatus, only at low loads and by correspondingly trained personnel, are fruitless as they are inadequate per se. All these items are described in detail and many examples of testing results are discussed.

A. Kochendorfer, Germany

766. Pilipchuk, B. I., and Stepanov, S. S., A new hardness number, *Indust. Lab.* **25,** 6, 795–796, June 1960. (Translation of *Zavod. Lab., USSR* **25,** 6, 764–765, June 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

767. Malmberg, G., Control test bars for pendulum impact testing machines, *Jernkontorets Ann.* **144,** 4, 281–287, 1960.

Experiments have been conducted with 3 × 10 × 55 mm test bars to establish whether such bars could be used for checking pendulum impact testing machines. The experiments were made on series of 10 test bars. The results show that, if the bars are manufactured in the manner specified and of suitable steel, they can be used for checking pendulum impact testing machines within the lower part of the testing range (up to about 4 kgm). Based on the results obtained in these experiments and on certain observations made in the course of the tests, the author presents certain views on the preparation of the test bars and on the determination of the control test value. From author's summary

768. Harding, J., Wood, E. O., and Campbell, J. D., Tensile testing of materials at impact rates of strain, *J. Mech. Engng. Sci.* **2,** 2, 88–96, June 1960.

A review is given of the techniques that have been used in the construction of dynamic tension-testing machines. The problems involved in obtaining reliable tensile stress-strain curves at high strain rates are discussed. A new apparatus, designed to give accurate stress-strain curves in tension at strain rates of the order of 1000 per second, is then described. The theoretical basis of the test method is indicated, and some experimental results obtained with the apparatus are presented, both for materials that exhibit a definite yield point and for those that do not.

From authors' summary

769. Taira, S., Tanaka, K., Ohji, K., and Harumoto, I., Creep of mild steel under periodic stresses of rectangular wave, *Bull. JSME* **2,** 8, 514–520, Nov. 1959.

Creep under constant and periodically varying stresses is compared for an annealed 0.14% carbon steel tested at 450°C. The periodic variations involved stepwise alternation between two stresses with equal time intervals at each stress. Data for stress ranges of 16 to 18 or 15 to 19 kg/mm^2 and time intervals of five to 2880 minutes are given.

Predicted strains for the variable stress tests using constant stress data and the Zener-Hollomon mechanical equation of state concept were within 10% of the experimental values. Limitations of this concept for general usefulness over wide range of test conditions are recognized and discussed; a concept incorporating recovery effects is proposed and discussed in general terms.

Other concepts and data pertinent to this general problem have been surveyed in ASTM Spec. Techn. Publication no. 260, 1959.

S. Yukawa, USA

770. Vick, G. L., and Hollander, L. E., Ultrasonic measurement of the elastic moduli of rutile, *J. Acoust. Soc. Amer.* **32,** 8, 947–949, Aug. 1960.

Four of the elastic moduli of rutile have been determined by measuring the velocity of 10-Mc ultrasonic waves. They are $C_{11} = 2.48 \pm 0.08$, $C_{33} = 4.52 \pm 0.08$, $C_{44} = 1.20 \pm 0.03$, and $C_{66} = 1.6 \pm 0.1$, all $\times 10^{12}$ d/cm^2. The remaining two, $C_{12} = 2.0 \pm 0.1 \times 10^{12}$ d/cm^2 and $C_{13} = 1.4 \pm 0.1 \times 10^{12}$ d/cm^2, were computed from the given data and Bridgman's compressibility data. These values are, with the exception of C_{33}, in good agreement with values computed from force constant data. No change in elastic moduli was noted upon reduction to a resistivity of 0.2 ohm/cm. It was noted that attenuation was greater in reduced than in fully oxidized rutile and was considerably greater in the *a* than in the *c* crystallographic direction.

From authors' summary

771. Oshchepkov, P. K., Internal flaw detection in opaque materials, *Indust. Lab.* **25,** 6, 716–720, June 1960. (Translation of *Zavod. Lab., USSR* **25,** 6, 684–689, June 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

772. Sherwood, P. W., Non-destructive techniques in power plant inspection, *Combustion* **32,** 4, 44–48, Oct. 1960.

773. Nazarov, S. T., Rozhdestvenskii, S. M., and Shraiber, D. S., The present state and development trends of nondestructive methods of material testing, *Indust. Lab.* **25,** 7, 799–804, June 1960. (Translation of *Zavod. Lab., USSR* **25,** 7, 771–778, July 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

774. Sorensen, S. V., and Borodin, N. A., Statistical processing of static long-time tests, *Indust. Lab.* **25,** 6, 752–756, June 1960. (Translation of *Zavod. Lab., USSR* **25,** 6, 722–726, June 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Properties of Engineering Materials

(See also Revs. 641, 756, 759, 769, 975)

Book—775. Hu, L. W., and Marin, J., edited by, Mechanical properties of metals (Proceedings of a short course held at Pennsylvania State University, July 7–11, 1958), University Park, Pa., Pennsylvania State University, 1958, 296 pp. $5. (Paperbound).

The scope of the book covers the major areas of endeavor that are of current interest in the metal materials field. There are papers dealing with the theoretical concepts for describing the behavior of materials, those concerned with the interpretation of experimentally acquired materials information and reports on the recent development in the equipment used in obtaining materials data.

A. M. Freudenthal (Chapter 1) discusses some of the fundamental concepts dealing with the mechanical properties of metals. Beginning with the atomic or molecular level of aggregation, the author develops formulations for describing the principal factors of interatomic forces and temperature used to determine the state of the aggregate. He next introduces the concept that the structure of a real material can be classified in terms of its position within the "order-disorder" spectrums ranging between perfect order (ideal crystal with 100% potential energy of the forces of interaction) and perfect disorder (ideal monatomic gas with 100%

kinetic energy of heat motion) and in terms of "mobility" ranging from complete immobility (0°K) to maximum mobility ("paracrystalline state" with continuous place-change of particles). The level of aggregation that permits the consideration of such structural imperfections as vacant lattice sites, dislocations, block boundaries and impurities is then discussed. This leads to the concepts of quasi-viscous deformations and deformation by slip in the crystalline region; both types are of significance in the deformation process of a polycrystalline metal alloy.

E. A. Davis (Chapter 4) initiates his discussion with the mathematical description of the elastic behavior of a material and then uses these formulations to compare the extent to which the plastic behavior deviates. This is followed by a lucid and yet concise development of the familiar equations describing the plastic behavior of materials and a comparison of the maximum shearing stress law and von Mises' criterion for predicting the start of plastic behavior. For obtaining a unique stress-strain diagram, Davis recommends the use of the octahedral stress and strain and, more specifically, the true octahedral stress and natural octahedral strain.

G. V. Smith (Chapter 5) highlights some of the more active fields concerned with the mechanical behavior of metals of elevated temperatures. In addition to the familiar creep and creep-rupture data and the parametric plots (Larson-Miller and Manson-Haferd) he also discusses, to a limited extent, the concept of "creep damage" (analogous to "fatigue damage") in connection with the metal's remaining useful life, the effect of notches during creep of a metal, the effect of combined fluctuations of load and temperature (combined fatigue and creep), the possibility of using a "hot hardness" test to provide an approximation for "long-time" strength and the importance of environment for elevated temperature conditions.

In Chapter 10, J. C. Wilson discusses some of the limited metals data dealing with the effects of irradiation. In particular, the changes in such mechanical properties as the tensile strength (raised slightly), the yield strength and hardness (raised) and the rate of work hardening (reduced) as related to increasing radiation flux are presented for type 347 stainless steel. This author cites as one major problem the increase in transition temperature in steels as the result of a large radiation dose.

The element of time and its effect on the mechanical properties of metals is discussed by T. J. Dolan in Chapter 6 in connection with the fatigue phenomenon. Dolan begins with a review of the microscopic behavior of materials and the mechanism of progressive fracture. He then points out that at the microscopic and phenomenological level of observation, the random nature of fatigue requires the use of a probability concept in recognition of the fact that damage is a statistical process.

Dolan next considers the over-all deformational response of a polycrystalline metal to be attributed to the joint operation of the anelastic, viscoelastic and plastic response as the three principal sources of energy dissipation within the elastic matrix. Simple idealizations for the elastic and plastic medium are then combined to describe the response of real materials within a specified range of conditions yielding, for example, a viscoelastic equation and for the three-dimensional state of stress, the generally used invariant relation describing a constant volume, inelastic deformation.

In connection with mechanical testing, Dolan argues that the real problem is the development of testing procedures that are meaningful in terms of design and are related to the expected performance of the material as it is used in the structure. In many instances, testing procedures reflect the desire for simplicity and ease of machine operation and an avoidance of the necessity of defining the really significant structural properties. Moreover, he continues, test results frequently reflect the manner in which a variable is measured rather than the actual behavior of the material. The specific factors that Dolan considers significant in determining the fatigue characteristics of a metal are those associated with production processing (specimen shape, size and surface finish), service environments (corrosion fatigue), the effect of mean stress, variations in stress amplitude, fretting fatigue and the effect of frequency and temperature (combined fatigue and creep).

F. B. Stulen and H. N. Cummings (Chapter 7) discuss in detail the methods of statistical analysis of fatigue data used in determining the degree of structural reliability and life of a product. They list three areas of fatigue knowledge that are necessary for a correct interpretation of statistical analysis:

a. A cycle-versus-load histogram for all load conditions, environments, and malfunctions the structure may experience in its service life.

b. The induced stresses at the most crucial points in the structure as directly related to the histogram.

c. The manner in which the manufacturing, assembly, inspection and the maintenance of the structure and the service loads influence the material variability must be considered.

The authors list the following purposes for which statistical analysis may be used:

(1) Design of machine components or structures
(2) Evaluation of service life and reliability
(3) Development of the "probability-stress-number of cycles to failure" curves
(4) Fatigue strength comparisons
(5) Development of basic fatigue mechanism hypotheses
(6) Comparison of the effects of variables on fatigue strengths
(7) Quantitative evaluation of the variability of fatigue life or strength
(8) Determination of assignable causes in fatigue tests

Stulen and Cummings then review the different methods of fatigue tests such as the "standard" tests (fatigue life at constant stress), the "response" tests (Probit, staircase and modified staircase methods) and the "increasing amplitude" tests (step and Prot method). The last part of the chapter is devoted to a discussion of ASTM Special Technical Publication No. 91-A, "A tentative guide for fatigue testing and the statistical analysis of fatigue data."

J. S. Rinehart (Chapter 9) discusses the failure of metals under impulsive loadings where the total load duration is at most a few microseconds. He begins with a review of some of the velocities used to denote the propagation of transient disturbances and this is followed by a description of means whereby impulsive loads are generated by explosive charges. The various fracture patterns arising under impulsive loadings (such as corner fractures, and scabbing) are discussed. The last section is devoted to plastic deformation under rapid loadings and the practical significance of the critical impact velocity and the related critical-normal-fracture stress.

F. G. Tatnall (Chapter 2) sets the stage for those chapters dealing with the techniques and equipment used for acquiring mechanical properties, with a brief, philosophical and retrospective look at the broad basic concepts of materials testing. V. E. Lysaght, in Chapter 3, discusses the various indentation hardness units currently available, the numerous problems relating to the proper use of the equipment and the need for standard reference guides ("test blocks"). He points out that the hardness test provides a quick and inexpensive means of quality control. A. J. Yorgeades (Chapter 8) discusses the characteristics, problems and applications of some of the commonly used mechanical types of fatigue machines. He expresses the opinion that some of the factors to be considered are those associated with the dynamic modulus of elasticity and the creep phenomenon, even for specimens where the maximum stress is substantially below the "elastic limit." The problems resulting from the use of "force-producing" mechanisms

such as hydraulic force mechanical oscillators are reviewed in detail.

Ib Jensen (Chapter 11) discusses some of the recent development in Riehle testing machines and related instrumentation. A high-temperature (up to 3000°F) extensometer for use with vacuum furnaces is one example. Other examples are a complete line of instrumentation and controls for adopting Universal Testing Machines to creep and relaxation tests for a wide range of capacities. Under consideration is a comprehensive program to develop equipment to evaluate changes in materials properties as the rate of loading or straining is increased to high levels. Another major program is that of equipment for fatique that will accommodate large deformations or loading strokes and a wide range of frequencies for a variety of many different size specimens.

B. L. Lewis discusses some of the developments in machines and instrumentation at the Tinuis Olsen Testing Machine Company. After a brief historical review of the development of the Tinius Olsen Testing Machine, he describes in some detail the electronic components used in load indicating and recording system. This is followed by a description of a Program Controller for stress or strain cycling, for controlled rates of loading, for holding duration of load and the equipment for the automatic determination of the yield strength of the offset method.

L. J. Rastrelli, USA

776. Gal'perin, M. Ya., Kostyukova, E. P., and Rovinskii, B. M., Influence of cyclic stresses on the structure of predeformed pure metals (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Metallurgiya i Toplivo* no. 4, 82–87, 1959.

Not fully understood is the fact that, after a number of cyclic loadings, certain previously plastically deformed metals recover to the conditions before the plastic deformation.

Reviewing the various explanations, author investigates the behavior of pure aluminum and nickel. After annealing strips of these materials, they are plastically deformed and thereupon put into a fatigue machine. At various stages, viz. after annealing, plastic deformation and certain numbers of cyclic loading, x-ray pictures were taken. With aluminum, the distortion of the crystal lattice due to the plastic deformation fully disappears after sufficient dynamic loading, which might explain the reinstatement of the original mechanical properties of the annealed material. With nickel, no recovery takes place, in agreement with the x-ray pictures. Roughly, with aluminum the required number of cyclic loadings increases with decreasing plastic predeformation. For a certain number of loadings the degree of recovery is about proportional to the amplitude of the cyclic stress.

R. G. Boiten, Holland

777. Schmidt, F. W., Farquhar, J., and Kurg, I. M., Effects of various aging heat treatments and solution-annealing and aging heat treatments on tensile, creep, and stress-rupture strengths of Inconel X sheet to temperatures of 1,400°F, NASA TN D-374, 32 pp., June 1960.

Authors present the effects of six different heat treatments on the tensile strength, on the minimum creep rate, on the 0.2% creep strength in 5 and 10 hours, and on the 10- and 100-hour stress-rupture strength of Inconel X sheet at 1000°, 1200°, and 1400° F. The aging treatments gave the greatest tensile strength for all test temperatures. Aging treatments, in general, were superior for the 0.2% creep strength in 5 and 10 hours and the 10-hour stress-rupture strength at 1000°, 1200°, and 1400°F. The solution-annealing and aging treatments had the best 100-hour stress-rupture strength at 1200°F, whereas a short aging treatment was superior at 1400°F.

From the authors' summary by H. T. Corten, USA

778. Reinberg, E., Criteria of linearity of the σ-lgN curve of titanium, *Indust. Lab.* **25,** 6, 761–764, June 1960. (Translation of *Zavod. Lab., USSR* **25,** 6, 731–733, June 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

779. Beresnev, B. I., Vereshchagin, L. F., and Ryabinin, Yu. N., A method of investigation of the effect of hydrostatic pressure upon the mechanical properties of prestrained metals, *Indust. Lab.* **25,** 6, 766–767, June 1960. (Translation of *Zavod. Lab., USSR* **25,** 6, 736–737, June 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

780. Stookey, S. D., Glass-ceramics, *Mech. Engng.* **82,** 10, 65–68, Oct. 1960.

781. Momin, A. U., Shankar, U., and Suryanarayana, N. P., Improvement of thermal conductivity of chemically resistant rubbers: Part 1, Thermal conductivity measurements, *J. Sci. Indust. Res., India* **19A,** 5, 215–218, May 1960.

Structures: Simple

(See also Revs. 608, 647, 662, 685, 686, 693, 701, 709, 710, 736, 749, 790, 793, 799, 808)

782. Vittoria, V., The mushroom slab and the beam with infinite moment of inertia at the ends (in Italian), *G. Gen. Civ.* **97,** 12, 5–27, Dec. 1959.

The literature concerning the mushroom slab is greatly extended, but the various proposed methods usually yield very discordant results. A comparative table is given. In most practical cases, the empirical A.C.I. method used in the United States is satisfactory. When special cases are encountered, however, it is necessary to use an analytical method based on the assumption that the mushroom zone has an infinite moment of inertia. The transmission and distribution coefficients of Cross method for a beam with infinitely stiff ends are calculated by the author and given in a table. A two-story five-bay frame is then fully calculated to show the use of these coefficients. The obtained results are compared to the A.C.I. rules and good agreement is found, except in the outer bay.

C. E. Massonnet, Belgium

783. Antia, K. F., Composite construction with steel beams, *J. Instn. Engrs., India* **40,** 11 (Part 1), 681–701, July 1960.

784. Ku, Y.-Y., Simplification of rigid frame analysis, *Scientia Sinica* **7,** 8, 871–884, Aug. 1958.

Author deals with the calculation of rigid frame structures the corners of which do not move laterally, and applies the Hardy Cross method as a starting point. In order to amend the convergence of the balancing of moments, the distribution factors of the moments have been replaced by the relative moments obtained after one circle of distribution, the circle of adjustment reaching only to the nearest corners (approximate method) or even to the following corners ("exact" method). Carry over factor 1/2 of the moment has been replaced by a value obtained in the corresponding way. The simplification of the calculations aims at obtaining, with only one circle of distribution, an end result sufficiently accurate for practical purposes.

In addition, the author has developed 22 diagrams for calculating the end moments of an elastically fixed beam for different loading conditions. The average multiplier for the stiffness factors of neighboring bars is assumed to be 0.9, of a hinged bar 3/4, and a fixed-end bar 1. The literature cited contains mainly Chinese and Russian publications and also Kloucek's known book,

in which a method for approximate calculation of frames is also presented. E. Niskanen, Finland

785. Rawlings, B., The general moment distribution analysis of space frames, *Struct. Engr.* **38,** 6, 185–195, June 1960.

Moment distribution relations are presented for three-dimensional rigid jointed structures including both orthogonal and skew members. Details of applications to three simple problems are included for which a desk calculator is satisfactory.

H. Becker, USA

786. Venkataramani, S., A study of encased portal frames, *J. Instn. Engrs., India* **40,** 11 (Part 1), 657–680, July 1960.

787. Baron, M. L., and Salvadori, M. G., Stresses due to thermal gradients in reactor shieldings, *Proc. Amer. Soc. Civ. Engrs.* **86,** EM 3 (*J. Engng. Mech. Div.*), 153–164, June 1960.

Paper presents method for calculating thermal stresses in a fixed arch such as reinforced-concrete rib which might be used to support reactor shield. Analysis considers case in which inner face is exposed to step function temperature rise and utilizes well-known one-dimensional heat-transfer solution for slab by assuming lateral and end boundaries are insulated and neglecting clearly small effects of curvature. End displacements and rotations are calculated by use of usual assumptions of beam and arch theory, and end thrust and moment required to restore compatibility are determined. J. E. Goldberg, USA

788. Albiges, M., and Goulet, J., Wind-bracing of tall buildings (in French), *Ann. Inst. Tech. Bât. Trav. Publics* **13,** 149, 473–500, May 1960.

Wind bracing of tall buildings may be provided either by full partition walls, by partition walls with openings, by rigid frames or, finally, by a combination of these elements. In this domain, the authors aim at finding simple solutions to the following problems:

- distribution of the general resultant of the wind pressures on the various wind-bracing planes;
- stability under wind action of a partition wall with or without openings, and of its foundations;
- distribution of the stresses in a rigid, symmetrical or asymmetrical frame, subjected to a system of horizontal forces;
- estimation of the horizontal displacement of the top of a partition wall or of a rigid frame.

Numerical examples illustrate the use of the formulas, and graphs permitting rapid calculation are appended to the note.

This paper, in the opinion of the reviewer, presents many new solutions to an increasingly important problem which is seldom discussed in the literature. It should be read by every engineer interested in the design of multi-story buildings.

From authors' summary by C. E. Massonnet, Belgium

Structures: Composite

(See also Revs. 654, 706, 730, 734, 735, 761, 784, 1102)

789. Durov, I. S., Calculations for the deformation of suspension bridges by the lines of influence (in Russian), *Trudi Novocherk. Politekhn. In-ta* **69/83,** 49–71, 1958; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 3205.

An approximate calculation for this deformation is undertaken for a single-span, braced suspension bridge equipped with a beam for rigidity, enabling lines of influence to be utilized, the concept being based on the acceptance of a constant coefficient of deformability which in its turn is actually dependent on the magnitude of the periodic load. It is shown that consideration for the influence of deformation results in an appreciable change of the deflection moments in the lightened beam of rigidity.

N. K. Snitko

Courtesy Referativnyi Zhurnal, USSR

790. Beaujoint, N., Global calculation of arched dams by the generalized method of arch-walls, with the aid of high-speed digital computers (in French), *Ann. Ponts Chaus.* **130,** 1, 1–93, Jan./Feb. 1960.

Paper gives a method for calculating arched dams by their approximation to a net of horizontal arches and vertical cantilevers. The method is more advanced and accurate than the well-known trial-load method.

By setting equality conditions for displacements at all the points of the network, the problem is reduced to solving a system of algebraic linear equations involving numerous unknowns. Calculations are systematized in view of using electronic computers. The results obtained are discussed in detail.

P. P. Teodorescu, Roumania

791. Pincus, I. R., Two aspects of sluice valve stress analysis, *Instn. Engrs., Australia,* EM **2** (*Elec. & Mech. Engng. Trans.*), 1, 9–12, May 1960.

In designing the valve gate of sluice valves it may be necessary to analyze the stresses in the gate fairly accurately, especially when the gate is large and high pressures are involved. This paper describes a method of carrying out this analysis by regarding the whole strength of the gate as being in the ribs, these ribs being uniformly loaded by the water pressure and supported by each other at the crossover points and by the rim at their ends.

The second aspect of valve design which is dealt with is the stress analysis of valve bodies under internal pressure. The valve bodies considered are roughly oval in horizontal section and are ribbed at intervals both internally and externally. The method of analysis is to consider the body to consist of several horizontal sections of uniform depth, each section including the same number or proportion of ribs. These sections are then treated as rectangles with the stiffness of the long side varying uniformly from the center of the side to the corners. A chart is provided which facilitates stress analysis of these sections by choice of bending moment coefficient for a range of valve body proportions and stiffness variations. Alternatively, the chart can be used to determine the required stiffness variation of the long side (obtainable by changing the rib proportions at the design stage), when it is desired to limit the stress at a particular section.

From author's summary

792. Itow, T., Calculation of sand pressure on the horizontal top surface of a tunnel or heading, *Technol. Rep. Osaka Univ.* **10,** 109–112, Jan. 1960.

Sand pressure on horizontal top surface of a tunnel or heading is calculated, based on experimental result that in case of yielding of the top surface sliding occurs in tangential direction on the surface of sliding which is formed in sand layer over the top surface and is elliptic. The results obtained show the sand pressure is independent of the height of sand layer and nearly equal to the value given by experiments. From author's summary

793. Blanjean, L., Summary of the studies of the Research Committee on Steam Piping in the field of analytical calculation (in French), *Rev. Tijdschr.-Mecan. Werk.* **4,** 4, 235–249, 1958.

Author discusses piping flexibility analysis by three methods, described as the flexibility method (methode des souplesses), the matrix method, and a generalized Hardy Cross method. He gives flexibility coefficients for various pipe sections (bends, etc.), and outlines the general philosophy and relative merits of each approach. Multibranch systems are included. No mention is made of extensive previous literature, e.g. Brock [AMR 6(1953), Rev.

2765], Soule [AMR 9(1956), Revs. 1766, 1767], M. W. Kellog Co. [AMR 9(1956), Rev. 1765], and many others.

J. L. Lubkin, USA

794. Jacob, K. B., Pipe ranges for water at high pressures and high temperatures with special reference to boiler feed systems, Instn. Mech. Engrs., Prepr., 1959, 14 pp.

With the pressures now being used for central station boiler plant, the feed water pipelines may be excessively stiff and distortion of feed pump bodies is possible owing to the thermal expansion of the pipes when carrying feed water at temperatures up to 500°F. Everything must, therefore, be done to increase the flexibility of the feed pipelines by providing an arrangement which will reduce the pipe thrust and bending moment on the pump terminals, by reducing the pipe bore and increasing the velocity consistent with economic pressure drop, and by reducing the pipe wall thickness to the limit imposed by the safe working stress for the available materials. From author's summary

795. Lakin, R. W., and Gill, S. S., Design of a reinforced cylinder for a nuclear reactor pressure vessel, Instn. Mech. Engrs., Prepr. 1960, 15 pp.

796. Wittrick, W. H., Stresses around reinforced elliptical holes, with applications to pressure cabin windows, *Aero. Quart.* **10**, 4, 373–400, Nov. 1959.

The problem of determining the stress distribution around window openings in pressurized fuselages is idealized to that of determining the stress distribution due to an elliptical hole, reinforced around its boundary. It is assumed that the hole exists in a plane sheet that is subjected at infinity either to an arbitrary constant stress system or to a bending-type stress system. Numerical results are given for a wide range of parameters, including three different shapes of ellipse and ten different amounts of reinforcement. Poisson's ratio was assumed to be 1/3. The analysis employs the complex variable methods developed by Muskhelishvili. L. A. Pipes, USA

797. Villa, V., A theoretical and experimental investigation of composite structures with particular consideration of resistance to fatigue (in Italian), Monogr. Scient. Aero. Rome no. 6, 200 pp., Dec. 1959.

Author describes an investigation conducted for the Italian Laboratory Directorate for Military Aeronautics. Composite sections made of thin laminations are analyzed theoretically and extensively investigated experimentally. Twelve models incorporating five different thicknesses each are studied under the action of point loads and fatigue conditions. Experimental results and theory are correlated in the attempt to arrive at design simplification of applicable validity.

Stress concentrations larger than those predicted by customary means appear to form at deformations above certain critical values. Improved calculating procedures for both initially undeformed as well as initially deformed structures are proposed. Results are thus procured which are independent of lamination thickness and length, requiring only an evaluation of the level of elongation. Calculation by these methods minimize the variations from actuality which previously existed.

J. P. Vidosic, USA

798. Williams, D., A general method (depending on the aid of a digital computer) for deriving the structural influence coefficients of aeroplane wings, Parts 1 and 2, Aero. Res. Counc. Lond. Rep. Mem. 3048, 58 pp., 1959.

Author presents a general method for the determination of structural influence coefficients for a wing, employing an indirect approach in which an arbitrary set of deflections is assumed and then the loads necessary to hold the structure in this assumed shape are calculated rather than the direct approach in which the known loads are placed on the structure and the resulting deflections are then determined. A digital computer is given the task of determining the deflection in any part of the structure for a given load which it accomplishes by inverting the matrices. From an engineering standpoint the author finds the resulting equations to be simpler than those obtained in the direct approach.

Part I of the paper presents three methods of varying degrees of accuracy. The first neglects the effect of shear deflections. The second method treats the shear and bending deflections separately. Shear deflections only in the vertical direction are considered, it being assumed that the structure is restrained so that there is no deflection in the other two directions. The third method takes into account the bending deflection and the shear deflection in all three directions.

Part II deals primarily with boundary condition problems encountered in the application of the methods in Part I to the following types of problems:

1. A constant thickness flat plate neglecting transverse shear deflections.
2. A hollow wing reinforced by one or more sets of parallel stringers neglecting shear deflections.
3. The determination of shear deflections when the shear is carried by one or more sets of shear webs.
4. A method of analysis applicable to thick wings.

A solution of a cantilevered flat plate loaded at one corner is presented in the appendix and is compared to a solution by the electric analog method by MacNeal and to measured deflectors. The agreement is good. G. L. Jeppesen, USA

799. Semenko, V. P., Calculations for steel smoke stacks (in Russian), *Trudi Groznensk. Neft. In-ta* no. 20, 219–228, 1958; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 3207.

A method is put forward for the engineering calculations of wind resistance loads of steel smoke stacks strengthened by guy ropes, used most extensively in the petroleum refining industry, dealing with the stability of the body of the stack, with the deformation of the walls of the stack and with the forces of tension on the guys; in the last case where single sets or double sets at different heights of guys are concerned the stack is looked upon as a beam with an evenly distributed load corresponding to the presence of two or three supports. C. V. Zhuravlev

Courtesy Referativnyi Zhurnal, USSR

Machine Elements and Machine Design

(See also Revs. 610, 655, 726, 972)

800. Huszthy, L., Determination of profile curves by computation (in Hungarian), *Gép* **11**, 2, 70–74, Feb. 1959.

For spur gears with a given gear ratio and distance between shaft centers, the Ruleaux construction is commonly used to obtain the profile curve of the pinion corresponding to a known profile curve of the driving gear. Author establishes that the graphical method can be replaced by analytical techniques for simpler cases. A completely general case is treated first, assuming only the quantities listed above to be given. The known profile curve is expressed as a complex function of time and a geometrical quantity. Application of the method is illustrated with two examples. N. A. Weil, USA

801. Bezborodnikov, M. F., Application of the method of interpolation with corrections to the approximate synthesis of mecha-

nisms (in Russian), *Trudi Inst. Mashinoved., Akad. Nauk SSSR* **20**, 77, 11–26, 1959.

In attacking the problem to reproduce a function by means of mechanical apparatus one has to bear in mind that every mechanism gives a family of curves depending on its parameters. The problem is to find such values of parameters that the apparatus in question could give as good approximation to the wanted function as possible. The classical method of Chebyshev consists in subsequently improving the roughly determined dimensions by additional corrections.

The present method of interpolation with corrections gives a remarkable generalization and improvement of the above-mentioned Chebyshev procedure. It starts with a fundamental polynomial of interpolation and gives a number of methods on how to correct its coefficients (depending on the parameters of the apparatus) to raise the degree of accuracy.

Numerical examples show that even quite simple polynomials of interpolation lead to approximations which are several times better than the results obtained by applying the method of Chebyshev.

V. Vodicka, Czechoslovakia

802. Bessonov, A. P., General investigation of the equations of motion of an assembly of machines (in Russian), *Trudi Inst. Mashinoved., Akad. Nauk SSSR* **18**, 70, 68–86, 1958.

In studying the motion of an assembly of machines with one degree of freedom we are often led to a nonlinear equation and it is impossible to solve it by analytical methods. The situation becomes particularly difficult if we cannot have enough of only one solution which can be obtained by numerical or graphical procedures.

Despite the impossibility of obtaining the general solution, there exist special means for getting valuable information concerning related family of integral curves. For instance, we can find the points where a solution has horizontal or vertical tangents and determine singular points of the basic equation.

The paper in question deduces a number of properties of the above-mentioned kind directly from the coefficients of the fundamental equation of motion. Having found geometrical loci of points where the integral curves have horizontal or vertical tangents and having determined singular points of the basic equation author discusses in detail the stability of the equilibrium at singular points.

Paper is abundantly provided with instructive diagrams. It will prove useful to interested specialists.

V. Vodicka, Czechoslovakia

803. Ganesh Rao, H. M., Kinematic analysis of plane mechanisms, *J. Instn. Engrs., India* **40**, 9 (Part 2), 305–316, May 1960.

804. Pisarev, M. N., Regarding the number of links in mechanisms relating to simple closed kinematic chains (in Russian), *Trudi Gor'kovsk. Politekhn. In-ta* **14**, 1, 88–91, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 4723.

The paper gives a general structural analysis of mechanisms in different groups. The correlation of the number of links and the number of kinematic pairs of different classes is the usual method of equalizing the number of steps of freedom of all the links and the number of linkages (taking into account the general linkages). It is shown that for the mechanisms of every group there is a specific number of links: with pairs of only the fifth class the mechanisms of the zero, first, second, third and fourth group have correspondingly seven, six, five, four and three links. The case is also investigated of introducing into the mechanism pairs belonging to other classes. It was demonstrated that not every combination of class of pairs is feasible in mechanisms of determined groups.

V. N. Geminov

Courtesy Referativnyi Zhurnal, USSR

805. Gerts, E. V., Dynamic characteristics of membranes of pneumatic apparatus (in Russian), *Trudi Inst. Mashinoved., Akad. Nauk SSSR* **18**, 71, 11–21, 1958.

The response of a pneumatically actuated rubberized membrane due to pressurization in a receiver is investigated. The stiffness of the back-up spring and the membrane has nonlinear characteristics which are treated as linear in several discrete segments. Resistance to the flow of the compressed air is taken into account. Good comparison with experimental results is reported.

E. P. Popov, USA

806. Denny, D. F., and Turnbull, D. E., Sealing characteristics of stuffing-box seals for rotating shafts, Instn. Mech. Engrs., Prepr., 1959, 16 pp.

There are two distinct modes of operation of a stuffing-box seal. One mode occurs when the axial pressures produced in the packing by tightening the gland-bush are greater than the sealed fluid pressure and the other when they are less. Under the former conditions the fluid pressure distribution is an exponential function of the packed length and the frictional torque increases rapidly with this quantity. With high fluid pressures, however, the relation between fluid pressure and packed length is no longer exponential and most of the fluid pressure drop occurs over the last 10 per cent of the packed length. In addition very little increase in frictional torque occurs when the packed length is increased.

Theoretical expressions have been derived for pressure distribution and friction torque and good agreement has been obtained between these and experimental results.

From author's summary

807. Miller, N., Dimension analysis of helical compression springs, *Prod. Engng.* **31**, 44, 52–57, Oct. 1960.

Fastening and Joining Methods

(See also Revs. 671, 978)

808. Grabner, R., On determination of loads on shear rings of pressure tubes (in German), *Öst. Ingenieur Z.* **2**, 12, 473–477, Dec. 1959.

Instead of assuming that outer longitudinal pressure force on the straight tube is uniformly taken by all rings and transmitted to concrete outside tube author calculates load distribution under certain specified assumptions. Considering elastic properties of tube and concrete he concludes that longitudinal outer force on one end gives a load distribution on rings in a geometric series. The load on a ring is independent of number of following rings. First ring gets highest load and number of rings can be determined from the condition that last ring, which takes rest of load, will not be more loaded than first one. A sample calculation is given. Radial interaction between tube and concrete has appreciable influence on ring loads and author estimates this interaction by assuming concrete as being thick-walled cylinder. Concrete shrinkage diminishes ring loads but is doubtful near tube and should therefore be disregarded.

E. R. Steneroth, Sweden

809. Shevchenko, N. I., Distribution of stresses due to deflection in butt-welded joints (in Russian), *Trudi Saratovsk. Avtomob.-Dor. In-ta* **15**, 1, 81–96, 1957; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 3259.

Author uses the method of the theory of elasticity for the problem and studies the field of stresses in terms of polar coordinates, examining the welded locus as if it were a wedge, loaded initially by a moment M and then by an intersecting force Q. Stresses σ_r, σ_θ and $\tau_{r\theta}$, as well as the principal stresses are determined; isoclines and isostats are drawn for both forms of stresses. The

stresses formed by the joint action of M and Q are found to be algebraical additions of the results of the solutions obtained. Comparison is made of the graphs of the distribution of stresses in the seam obtained theoretically and experimentally. The results were close to convergence with the exception of a few loci in which there was a concentration of stresses not taken into account in the theoretical calculations. G. A. Nikolaev

Courtesy Referativnyi Zhurnal, USSR

810. Ivanova, T. I., Influence of heterogenity of butt welded seams on the character of their deformation during static deflection (in Russian), *Svarochnoe Proiz-vo* no. 12, 17–21, 1957; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 3260.

Investigations are carried out on welded joints as regards the relations between the limits of flow of the welded seam and the main body of metal, evaluated by means of the coefficient K and by the form of the butt weld. Experiments for deflection under static load disclosed the formation of plastic deformations of considerable magnitude in the zone of butt welding with $K < 1$ and the absence of any with $K > 1$. The curve bore a linear character with $K = 1$. It is assumed that magnitude K exercises a significant influence on the distribution of the elasto-plastic deformations, while the form of the seam is practically neutral in its influence. With $K = 1.1$ the character of the deformation of the joints differs little from the deformation of the main metal.

G. A. Nikolaev

Courtesy Referativnyi Zhurnal, USSR

811. Kravchenko, V. N., An investigation of the vibrational strength of lap-joint welding with stress deconcentrators, using the photoelasticity method (in Russian), *Trudi Mosk. In-ta Inzh. Zh-d. Transp.* no. 101, 144–166, 1958; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 3261.

An examination is made of the positive influence exercised by stress deconcentrators. The use of the method of photoelasticity is recommended for the study of the concentration coefficients; the experiments carried out are described. A new method is proposed for calculating the connections of the components of bridge structures. Recommendations are made to use compensators and to vary the ratios of the magnitude of the radii of the fillets to the width of the components and to select such sections for the compensators which will ensure their equality of strength with the basic element. G. A. Nikolaev

Courtesy Referativnyi Zhurnal, USSR

812. Sataev, Yu. P., Influence of low temperatures on the stability of welded joints in bridge constructions (in Russian), Soobshch. N.-i. In-ta Mostov Pri LIIZhT no. 50, 1957, 28 pp. + illus.; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 3265.

Test samples of welded joints made of steel of brand M16S were tested by means of static, vibration and impact loads at temperatures from +20 to −35° and −50°. In samples with a "not high" concentration of stresses (up to 1.5) the lowering of the temperature increased the static, vibration and impact toughness. With increases in stress concentration at the critical temperature the limit of strength of the joints dropped. The critical temperature of the welded joint is found to be in almost a linear linkage with the coefficient of stress concentration. Test samples with holes in them showed low plastic properties, reduced work of deformation and increased sensitivity to brittle fracture.

A. Ya. Brodskii

Courtesy Referativnyi Zhurnal, USSR

813. Ivanchenko, F. K., Investigation of the loads on the mechanisms of load-lifting machines with consideration for the flexibility of the links (in Russian), Vopr. Teorii i Rascheta Pod'emno-Transp. Mashin., Moscow-Leningrad, Mashgiz, 1957, 31–41; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 3279.

The process of lowering and stopping of this equipment is investigated with the help of the linear theory and calculations are made for the dynamic loads on the mechanisms during the working of overhead cranes. I. I. Trapezin

Courtesy Referativnyi Zhurnal, USSR

814. Mosborg, R. J., Behavior of riveted and welded crack arrestors, Ship Structure Comm., Natl. Acad. Sci.-Natl. Res. Counc., Washington, D. C., Rept. no. SSC-122 (Contract NObs-65789; BuShips no. NS 021-201), Aug. 1960, 114 pp.

815. Stanyukovich, A. V., and Zemzin, V. N., Methods of determining the long-time strength of welded joints, *Indust. Lab.* **25**, 6, 746–752, June 1960. (Translation of *Zavod. Lab., USSR* **25**, 6, 715–721, June 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Rheology

(See also Revs. 665, 737, 742, 836, 1163)

816. Reiner, M., Cross stresses in the laminar flow of liquids, *Physics of Fluids* **3**, 3, 427–432, May/June 1960.

Experimental investigation of cross elasticity effects in a simple homogeneous liquid (toluene) is described. By observing the separation of a horizontal rotor and spring-supported stator, which are in contact when at rest, previous theoretical work is checked in part.

No conclusive results are obtained as to the relative merits of different stress-strain relations.

S. R. Montgomery, England

817. Reiner, M., Research on cross-stresses in the flow of liquids: Part 1, Cross-stresses in the laminar flow of liquids; Part 2, Centripetal air-pump operated electromagnetically, Tech. Res. Dev. Foundation, Ltd., Haifa, 18 pp., Mar. 1959/Feb. 1960.

Part I. It is shown that cross-elasticity effects exist in a simple homogeneous liquid such as toluene. These effects manifest themselves in cross-stresses observed in an instrument consisting of two circular metal plates, one stationary, the other rotating opposite it. The stator can be displaced along the axis of rotation against forces exerted by springs. Stator and rotor are in contact when at rest. When the rotor is brought into rotation, cross-stresses in the liquid separate stator and rotor and a bearing effect is produced.

Part II. An instrument is described which works both as a centripetal air-pump and as a self-acting air-lubricated thrust bearing.

From author's summary

818. Maude, A. D. The viscosity of a suspension of spheres, *J. Fluid Mech.* **7**, 2, 230–236, Feb. 1960.

Previously Einstein obtained an expression for the viscosity of a suspension composed of a fluid and spherical particles with volumetric concentration C. The well-known equation is $\eta = \eta_0 (1 + 2.5C)$, where η and η_0 are, respectively, the suspension and fluid viscosities. Present author obtains a more generalized result, viz., $\eta = \eta_0 (1 - 2.5C)$, which is in agreement with Einstein's expression for small C and with Kynch's power series equation for larger values of C. Author's expression is also in agreement with experimental data up to a value of $C = 0.28$. Author suggests that discrepancy between his expression and experimental data for C greater than 28% may be due to divergence of his series solution.

R. B. Banks, USA

819. Vyalov, S. S., Rheological processes in frozen soils and the conditions governing their boundary equilibrium (in Russian),

Materialy po Labor. Issled. Merzlykh Gruntov, no. 3, Moscow, Akad. Nauk SSSR, 1957, 234–254; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 3080.

The first part of the paper consists of an analysis of the different relations applicable in the study of rheological processes in frozen soils. Attention is drawn to the fact that the linear relations containing differential time-restricted operators, as shown in the tests, do not describe the real properties of the frozen soil. The rheological properties of a frozen soil, in agreement with the author's tests, are better described by means of nonlinear relations developed by Yu. N. Rabotnov [*Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 6, 789–800, 1948] and the abstractor [*Zh. Tekh. Fiz.* **21**, 11, 1311–1318, 1951] which contain integral operators. Together with the author's last-named relations he proposes to utilize a clear relation of his own between stresses and deformation which does not contain the operator elements referred to previously

$$\varepsilon = \frac{\sigma}{E(t)} + \left[\frac{\sigma}{A(t)}\right]^{1/\alpha} \qquad [1]$$

where $\alpha < 1$ is the compacting coefficient, E the modulus of elasticity, A the deformation coefficient, t time. Relation [1] takes account of the change by time of the position and configuration of curve in the coordinate system of deformation–stress for different fixed moments of time. Concluding this part of the paper the fact is noted that if the load has not reached the limit of prolonged stability then the linkage between ε and σ can be described by a graduated relation of type [1]. Should the load be increased for the given limit the process of deformation will be characterized by a relation between the steady velocity of plastic flow ζ_T and the excess stress above the limit of prolonged stability τ_p, that is

$$\zeta_T = \frac{1}{\eta}(\tau - \tau_p)^{\beta}$$

where η is the viscosity coefficient, parameter β being close to unity. Three methods are given for the determination of the limit of prolonged stability τ_p.

An investigation on the resistance to shear of frozen soils with due consideration for the influence of the time factor is the subject of the second part of the paper. The formula $\tau = c(t) + \sigma \tan \varphi(t)$ is proposed which is a generalization of Coulomb's equation and which reflects the relation between the forces of shear and the normal stress. Parameter $c(t)$ reflects that part of the resistance to shear which does not depend on the normal stress, while (t) characterizes the increase of τ with the increase of σ. It is noted that c and φ depend not only on the time t but also on the temperature of the frozen soil, its water content and density.

M. I. Rozovskii

Courtesy Referativnyi Zhurnal, USSR

Hydraulics

(See also Revs. 746, 779, 791, 794, 919, 923, 931, 1004, 1015, 1122, 1127, 1129, 1144, 1153)

820. Simmons, W. P., Jr., Models primarily dependent on the Reynolds numbers, *Proc. Amer. Soc. Civ. Engrs.* **86,** HY6 (*J. Hydr. Div.*), 59–74, June 1960.

Author discusses known facts in design, construction and operation of models of closed-conduit fluid systems. He considers primarily experiments in fully developed turbulence, using the Reynolds number as a criterion of the reliability of the model.

H. J. Schoemaker, Holland

821. Litwiniszyn, J., Flows in pipe networks from the point of view of the theory of random processes (in English), *Arch. Mech. Stos.* **11,** 4, 421–440, 1959.

This investigation is motivated by the following problem: given a ventilation network and the appearance of smoke at some point in the network, what is the danger of smoke appearing at other points in the network? The practical implications are evident.

Modern mathematical techniques are used in a very interesting manner in this paper. While the analysis is only carried to the stage of working a very simplified schematic example, reviewer believes that engineers with some background in matrix theory will find it a worthwhile example of the application of modern algebraic and topological concepts to a physical problem. Such techniques have found extensive application in electrical engineering.

W. Squire, USA

822. Skorodumov, D. E., On the drawing of a looped curve for discharges (the flood loop) when no measurements for the discharge of water are available (in Russian), *Trudi Gos. Gidrolog. In-ta* no. 47, 25–37, 1955; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5088.

The problem is put forward of finding by means of calculation the relation between the levels and the discharges of water in a river at the time of flooding; in particular, a method is proposed for the determination of the "rise" side of the relation referred to in conditions where, when the "fall" side is known as the result of hydrometric measurements carried out in the river, or the reverse, the determination of the "fall" branch when the "rise" branch is known. The author safeguards his view by stating that the method is only applicable in conditions where there is a stable lower water, with no inflow into it and in the absence of variable tributaries. For the working out of the method the usual correlation is employed.

$$\frac{Q_2}{Q_1} = \sqrt{\frac{I_2}{I_1}}$$

where Q is the discharge of water, I the slope of the surface (indices show the reference of the magnitude to two regimes, differing from each other by the values for the slope and the discharge while serving unchanged the depth of the flow), and also the correlation

$$I = i_c + \frac{\Delta H}{\Delta t}\frac{1}{\omega}$$

where i_c is the slope when the flow is steady, ω the velocity of propagation of the front of the wave (averaged for a period of time Δt), ΔH is the variation in this period of time of the depth in the line of direction for which the curve for the discharge is being sought; in this manner the second item in the right-hand side represents a supplementary value for the slope of the water's surface by comparison with the value when the motion is steady. The author considers that the determination of the values for the magnitudes i_c and ω was the most difficult of all. In connection with the above some recommendations of an approximate character are furnished.

V. A. Arkhangel'skii

Courtesy Referativnyi Zhurnal, USSR

823. Murota, A., On the secondary flow in open channels: Part 1, Secondary flow generated by the inertia of non-uniform flow in open channels, *Technol. Rep. Osaka Univ.* **10,** 85–96, Jan. 1960.

Relations between the secondary flow in open channels and the acceleration of nonuniform flow are investigated in Part I. It is verified analytically and experimentally that a sort of secondary flow can exist in the positive or negative accelerated flow (for instance, convergent or divergent channel flows).

The secondary flow near the branching point of the channel with a distributary and its effect on the distribution of sediment loads transported from the upstream are mentioned in part II.

From author's summary

824. Zarea, S., A comparative study of trapezoid canals and of parabolic canals, considered from the hydraulic standpoint (in Roumanian), *Hidrotehnica* **4,** 3, 90–94, Mar. 1959.

An optimum trapezoidal channel and a parabolic one, equivalent from the hydraulic point of view, are compared. Author concludes that parabolic channels have better hydraulic characteristics than the trapezoidal ones. Some numerical examples are presented.

D. Gh. Ionescu, Roumania

825. Nikitin, A. K., and Snopov, A. I., The motion of water in a horizontal settling tank (in Russian), *Sb. Statei Vses. Zaochn. Politekhn. In-ta* no. 17, 105–112, 1957; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5106.

The theoretical portion of the paper is devoted to the question of determining the field of velocities of a flowing liquid in a horizontal settling tank with the following assumptions in force: (1) the settling tank has the form of a long rectangular vessel; (2) the admission and release of the liquid is effected by copies of actual sources and run-offs of identical intensity in the vertical section of the settling tank, disposed unsymmetrically on opposite sides of the rectangular vessel; (3) the flow of liquid in the settling tank is taken to be steady, potential, plane (in the vertical transverse section). An approximate expression is found by using known methods for the complex potential of the velocities. The experimental portion of the study is devoted to a number of investigations concerning the flow of water in a model of the settling tank. The experiments show that, in the conditions adopted for carrying them out, the material importance of the observations of the current's flow in the zone of admission of liquid into the settling tank is paramount.

V. P. Pilatovskii

Courtesy Referativnyi Zhurnal, USSR

826. Turapin, V. M., Vortex resistance in a compressible liquid (in Russian), *Trudî Kuibyshevsk. Aviats. In-ta* no. 5, 49–55, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 4809.

The field of velocities is found for Karman's vortex track in Chaplygin's gas at a Mach number of $M < 0.6$. When calculating the resistance the hypothesis due to Kamenkov is accepted; this states that the resistance has an extremal value.

M. I. Gurevich

Courtesy Referativnyi Zhurnal, USSR

827. Sidorov, O. P., Some axisymmetrical potential flows of an incompressible liquid (in Russian), *Izv. Vyssh. Uchebn. Zavedenii, Aviats. Tekhn.* no. 1, 37–42, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 4969.

The liquid is ideal and incompressible. The flow-about of a continuous body of rotation is investigated and also of a circular body of rotation and of a combination of the circular body of rotation with the continuous body situated inside. Integral equations are obtained for the determination of the velocity on the surfaces of the bodies by using the methods for the theory of the potential. The questions are investigated of the uniqueness of the solution of the integral equations and of the convergence of the method of successive approximations. The article deals only with the idea of furnishing proofs.

M. I. Gurevich

Courtesy Referativnyi Zhurnal, USSR

828. Shul'gin, D. F., Motion of a slightly curved permeable surface of rotation (in Russian), *Trudî Sredneaz. In-ta* no. 54, 137–146, 1954; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 4978.

The problem given in the title is investigated, the flow consisting of an ideal liquid. The problem is linearized; a singular integral equation is derived for the intensivity of the vortex (the line of integration—a cutting of the actual axis). A method is demonstrated for the approximate solution of this equation: the solution is expressed as the product of a polynomial with unknown coefficients and the determined elementary function. The unknown coefficients are derived from a system of algebraic equations.

G. F. Mandzhavidze

Courtesy Referativnyi Zhurnal, USSR

829. Surova, N. N., Changes in the magnitude α, at different lengths for the horizontal reinforcement (in Russian), *Izv. Akad. Nauk UzSSR, Ser. Tekhn. Nauk* no. 1, 59–64, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5095.

The main results are given for experiments carried out to determine the depth of scouring beyond the horizontal rigid reinforcements not fitted with dampers. The depths of scouring found are utilized by means of M. S. Vyzgo's method for the calculations of the values of the correction factor for the kinetic energy. The conditions for the experiments are described very briefly, several designations are not referred to, the method of evaluation for the cessation of the process of scouring is left unexplained, and so forth. Comparison with the data of the abstractor's experiments appears to be of a provisional character.

D. I. Kumin

Courtesy Referativnyi Zhurnal, USSR

Incompressible Flow

(See also Revs. 592, 820, 870, 892, 894, 895, 900, 904, 909, 925, 929, 981, 1004, 1020, 1054, 1060, 1073, 1157)

830. Serrin, J., A note on the existence of periodic solutions of the Navier-Stokes equations (in English), *Arch. Rational Mech. Anal.* **3**, 2, 120–122, Apr. 1959.

In previous paper [AMR **13**(1960), Rev. 4655] author derived some sufficient conditions for the stability of the motion of a viscous fluid confined between finite boundaries.

Here these conditions are applied to the case of time periodic boundaries. It is shown that a periodic solution exists and remains stable for $t \longrightarrow \infty$, provided that it is initially stable according to the conditions mentioned above.

L. S. Rintel, Israel

Book—831. Vasil'ev, O. F., Bases of helical and circulating flows (in Russian), Moscow-Leningrad, Gosenergoizdat, 1958, 142 pp. + illus. 4 r 55k; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 4984.

The book consists of an investigation of the theoretical bases of the comparatively little studied section of hydrodynamics—the mechanics of spiral and circulation flows. The author limits himself to cases of inviscid incompressible liquids. The introduction expounds some concepts on the applicability of the theory of spiral motion to a series of questions in engineering. Chapter 1 is a brief account of the development of the theory of helical and circulation flows. A doctorate thesis written by the originator of the theory of spiral and circulation flows, U.S. Gromek "Some cases of the motion of incompressible liquids" (Kazan', 1881), is critically reviewed. A review is also furnished of studies bearing on the subject by E. Beltrami, L. Lecornu, A. Ya. Milovich, M. V. Potapov, S. S. Byushgens, S. G. Popov, B. A. Pyshkin and others. Chapter 2 deals with the general differential equations for circulation and helical flows of inviscid liquid. An investigation is carried out of double-parametric flows (the so-called flows which can be referred to a coordinate system of a type in which all three components of velocity are functions of only two components and are independent of the third). Differential equations are derived for two-parameter vortex and helical flows in a special system of orthogonal curvilinear coordinates, in a Descartes system of rectangular coordinates and in cylindrical and spherical systems of coordinates. The characteristic properties of these flows are described. The chapter concludes with an analysis of a single-parameter flow.

Chapter 3 is devoted to approximate differential equations for circulation and helical flows. A method is proposed for the linearization of the basic equations of two-parameter vortex and spiral flows, which, in most of the cases, appear to be nonlinear elliptical equations in special derivatives of the second order. The

general equation for the flow with a transverse circulation in a prismatic stream has the form

$$\Delta\psi + \Psi(\psi) = 0 \qquad [1]$$

where function

$$\Psi(\psi) = \Phi(\psi)\Phi'(\psi) + F'(\psi) \qquad [2]$$

reflects the distribution of the longitudinal velocity $w = \Phi(\psi)$ and the energy $E = F(\psi)$ on the transverse section of the flow. The author resolves the nonlinear function $\Psi(\psi)$ into a stepped series, limiting himself approximately by the linear expression

$$\Psi(\psi) = a_0 + a_1\psi \qquad [3]$$

The next stage is to substitute for equation [1] the approximate linear equation

$$\Delta\psi + k^2\psi = -C \qquad [4]$$

where $C = a_0$, $k^2 = a_1$. If function $\Psi(\psi)$ is taken to be a constant then

$$\Psi(\psi) = a_0 \qquad [5]$$

and

$$\Delta\psi = -C, \qquad (C = a_0) \qquad [6]$$

The simplified equations [4] and [6] will be linear differential equations. The approximation, based on the assumption in [5], is termed the first approximation by the author, while the more precise approximation based on the general linear expression for $\Psi(\psi)$ is called the second approximation. The linearization is also examined of the equations for axially symmetrical circulation and helical flows. Conditions are established, necessary and sufficient to ensure that when two helical flows of incompressible liquid are combined the flow obtained shall also be helical. The proposed method of superimposing helical flows represents actually a generalization of the known method of superimposing potential flows.

Chapter 4 is concerned with the helical and circulation flows in a prismatic stream. An example is given of the integration of linearized differential equations for the case of a double parametrical helical flow in a prismatic stream of rectangular transverse section. An investigation is also made of a homogeneous helical two-parameter flow, viewed as a special case of a linearized flow. An example of the calculation is furnished. The chapter concludes with an examination of the influence of unevenness of distribution of the energy in the transverse section on the velocity distribution of the circulation flow. Chapter 5 is taken up with the study of axially symmetrical helical flows. Flows are examined which have been formed by helical sources and channels and which appear to be analogous to and generalizations of potential sources and channels. The problem is investigated of a homogeneous helical flow of finite depth, running into the channel. The solutions given are intended for use in explanations of the principles of distribution of velocities in the flow of liquids with the formation of air eddies. A helical flow in a curved channel is also examined. An example of the calculation is given. N. A. Pritvits

Courtesy Referativnyi Zhurnal, USSR

832. Billerbeck, W. J., Jr., Empirical equation for the wake-spreading limits behind three-dimensional bodies, *J. Aero/Space Sci.* **27,** 8, p. 640 (Readers' Forum), Aug. 1960.

833. Kotlyar, Ya. M., An approximation for the Reynolds equation, *Soviet Phys.-Doklady* **5,** 1, 31–35, July/Aug. 1960. (Translation of *Doklady Akad. Nauk SSSR (N.S.)* **130,** 1, 41–44, Jan./Feb. 1960 by Amer. Inst. Phys., Inc., New York, N. Y.)

834. Case, K. M., Edge effects and the stability of plane Couette flow, *Physics of Fluids* **3,** 3, 432–435, May/June 1960.

The author investigates the effects of edges on the stability of plane Couette flow under the assumption of an infinite Reynolds number. A simple model is used for the investigation, which consists of a semi-infinite plate ($0 < x < \infty$, $y = 0$) at rest, and a parallel infinite plate ($\infty < x < \infty$, $y = y_1$) moving with a constant velocity in the x direction. The author determines that in this case an ordinary perturbation vanishes at least as rapidly as if both plates were infinite; the edges, therefore, do not change the stability properties of the type of Couette flow under consideration.

J. Polasek, Czechoslovakia

835. Reid, W. H., Inviscid modes of instability in Couette flow, Brown Univ., Div. Appl. Math. TR 30 (Contract Nonr-562(07) (NR-062-179)), 27 pp., Jan. 1960.

Author considers stability of inviscid, incompressible flow in the narrow gap between two concentric, rotating cylinders. Particular attention is given to the stability characteristics as the direction of rotation of one of the cylinders changes sign. When the cylinders rotate in the same direction, only one mode of instability is present. However, when the cylinders rotate in opposite directions, the modes of instability may be either periodic or aperiodic. Because of the assumption of vanishing viscosity, no criterion for the onset of stability can be obtained from the analysis. H. A. Stine, USA

836. Dombrowski, N., Hasson, D., and Ward, D. E., Some aspects of liquid flow through fan spray nozzles, *Chem. Engng. Sci.* **12,** 35–50, 1960.

Flow pattern of liquid sheet produced from a rectangular-orifice fan-spray nozzle was investigated, with emphasis on the manner in which its thickness varies from the orifice to the point of breakup. The trajectory of its boundary is analyzed on the assumption that the curvature of the edge of the sheet is due to surface tension. After surveying previous experimental methods for measuring the sheet thickness, the used apparatus, with double-reflection illumination, is described. Measurements of trajectory were made on the large clear photographs obtained. Main results are: (a) The streamlines of the spray sheet are straight and unaffected by the curved boundary. Velocity along the streamlines is constant, and independent of viscosity. (b) Sheet thickness at any point is inversely proportional to distance from the orifice, and can be expressed, for a given set of operating conditions, by a thickness parameter. (c) At low injection pressure the thickness parameter is a function of surface tension and of a factor composed of the injection pressure, density, and viscosity; at high injection pressure the thickness parameter is a function of the factor only (but not of the surface tension). (d) The trajectory of the sheet is a function of injection pressure, sheet thickness, and surface tension, and is independent of liquid density.

Advantage of method is that the entire sheet is depicted in one photograph, taken at 1/50-sec exposure, and its clarity permits an accurate evaluation. This is a highly informative paper, with clear exposition of the principles used, employing a well-conceived, simple, and effective experimental technique.

K. J. DeJuhasz, USA

837. Dokuchaev, N. F., An experimental investigation on the flow of a liquid close to the boundary of phase separation (in Russian), *Sb. Rabot. Vses. Zaochn. In-ta Pishch. Prom-sti* no. 3, 26–35, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5306.

The problem is investigated of the mechanism of the flow of a liquid close to the boundary of phase-separation and the influence of the-nature of the substance of the surface on the formation of a zone of flow in front of the wall. The experimental apparatus is described and two methods for measuring small velocities; there are also descriptions of a number of experiments, carried out for the purpose of comparing the flow-over of surfaces, differing as regards the nature of the substance but with no other change in the conditions. The velocity of the flow varied between 1.2 and 0.54

mm/sec. The experiments show that the fall in the kinetic energy of the flow depends on the nature of the substance of the surface.

Yu. G. Burov

Courtesy Referativnyi Zhurnal, USSR

838. Broecker, E., The mixing of liquid or gas streams at small changes in total pressure, Parts 1 and 2 (in German), *Forsch. Geb. Ing.-Wes.* **24,** 6, 169–177, 1958; **25,** 1, 17–25, 1959.

The comprehensive paper is subdivided into the following sections: (1) Introduction and nomenclature; (2) Determination of the mixing ratio; (3) Efficiency and energy consumption; (4) Approximate equations; (5) Graphic determination of pressure and mixing ratios; (6) Sample computations; (7) Test apparatus; (8) Measurements with cylindrical mixing tube; (9) Measurements with divergent mixing tube; (10) Measurements with convergent mixing tube; (11) Characteristic equations for mixing tubes; (12) Summary; (13) Bibliography.

Though basically another one-dimensional treatment of subsonic mixing processes, paper gives a good survey on the essential parameters. Particularly the influence on the mixing process of the system losses upstream and downstream of the mixing section are well treated. The theoretical pressure ratios and mixing efficiencies for the most important mixing geometries are graphically presented. Experimental confirmation of theory is given and the importance of wall friction losses is estimated (and found to be negligible).

Finally, characteristic equations are developed for the mixing process in analogy to the terminology of fluid machinery. It is shown that the mixing processes can be expressed in pressure and volume flow numbers and that an almost linear dependence of the two numbers exists when the ratio of the cross sections of driving stream and mixing tube is sufficiently small.

Paper should be well-suited for quick estimates of optimum mixing geometries, pressure ratios, and mass flow ratios, and can easily be expanded to problems similar to those treated.

H. J. Ramm, USA

839. Wagner, R., A flow problem with a non-unique solution (in German), *ZAMM* **38,** 11/12, 427–431, Nov./Dec. 1958.

Two-dimensional problem of plane jet impinging on an infinite plate perpendicular to and with aperture coaxial with axis is solved using hodographic method and conformal mapping. Two solutions are obtained if aperture width d is slightly greater than jet width b, viz: $1 < d/b < 1.01$. The two solutions differ in the ratio between jet flux and total flux of flow through aperture. For $d/b > 1.01$ the jet passes undisturbed through the aperture.

J. O. Hinze, Holland

840. Cunsolo, D., On the lift drag of the infinite wing with reference to the momentum and energy theorems (in Italian), *Aerotecnica* **39,** 3, 126–132, June 1959.

In incompressible flow the starting vortex (with circulation $-\Gamma$) generates on the infinite wing of constant chord (with circulation Γ) a drag per unit width $D = \rho\Gamma^2 (2\pi l)^{-1}$, where ρ air density, l distance from the starting vortex traveled by the wing. The energetic origin of this transient drag is explained. By treating the infinite wing with chord c in the transient state as equivalent to a finite wing of aspect ratio $4l/c$ it is shown that the mass m of air influenced in each second by the wing is proportional to the square of the wing span b. So it can be shown that this air's kinetic energy at constant momentum (and thus the induced wing drag) tends to zero as m (and thus b) tends to infinity. Finally, as an example, the kinetic energy associated with an elliptic distribution of lift is calculated and its identity with the work done on the fluid by the induced drag is shown.

H. Behrbohm, Sweden

841. Shmeter, S. M., Motion of a sounding balloon in an accelerating air flow (in Russian), *Trudi Tsentr. Aerol. Observ.* no. 22, 17–21, 1957; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5280.

The problem is investigated of the evenly accelerated vertically directed motion of an atmospheric flow. The differential equation for the problem is recorded by the author in the form of

$$m_w \frac{dU_w}{dt} = m_l \frac{dU_l}{dt} + m_{pr} \frac{d}{dt}(U_l - U_w) + (m_l - m_w)\, g - \frac{c_x q_l S}{2}(U_l - U_w)^2$$

Here m_w, m_l and m_{pr} are the mass of the balloon, the mass of the displaced air and of the attached mass, respectively, t is the time, g represents the accelerated forces of gravity, q_l is the density of the air, c_x is the coefficient of resistance, S is the area of the middle section of the balloon; U_l and U_w are the absolute velocities of the motion of the balloon and of the air; they are considered to be dependent on the time t; the remaining magnitudes are considered to be constants. After some simplifications the problem merges with the integration of the following differential equation

$$\frac{dz}{B - ft^2} = dt$$

where B and f are considered to be constants. As an initial condition it is assumed that $U_l = 0$, $U_w = \overline{U}_w = \text{const}$ with $t = 0$, that is, the assumption is made that in the initial moment the balloon ascends at a constant velocity in a motionless atmosphere. Two cases are investigated: (1) $B > 0$, and (2) $B < 0$. In each case an analysis of the solution obtained is given. The paper contains misprints.

Sh. A. Musaelyan

Courtesy Referativnyi Zhurnal, USSR

842. Kretzschmer, F., The sizing of regulating valves (in German), *Regelungstech.* **7,** 10, 351–355, Oct. 1959.

Author compares two different approaches to the problem of choosing the correct type and size for regulating valves: the first approach is based upon the knowledge of the discharge through the valve per unit head-loss, while the second one takes into consideration the resistance coefficient of the valve.

It is shown that, though the two approaches are fundamentally the same, the first one can be more easily used for practical purposes. Based on this approach, diagrams are drawn by means of which a quick choice of the valve is possible, once the extreme working conditions are given.

P. L. Romita, Italy

843. Daniels, C. M., and Fenton, R. E., Determining pressure drop in flexible metal hose, *Mach. Design* **32,** 21, 195–198, Oct. 1960.

844. Papai, L., Examination of the starting section in pneumatic grain conveying (in English), *Acta Technica Acad. Sci. Hungaricae, Budapest* 14, 1/2, 95–111, 1956.

Author has submitted a detailed analytical investigation of the acceleration process in grain transport. It consists primarily of an application of Newton's Second Law of Motion, employing empirical drag coefficients to express gas drag forces. The author treats only very lightly loaded gas flows; i.e., the grain spacing is large. In order to assess the practical design value of this work, the author's predictions should be compared with experimental results.

Similar work has been performed by the following authors:

1. Lewis, W. K., and Hellinchx—unpublished I.L.O. Report no. 53–155, May 1933, M.I.T.
2. Harin, O. H., and Molstad, M. C., *Indust. Engng. Chem.* **41,** 6, 1148–1160, 1949.
3. Hettich, B. V., and A. H. Kean, M.S. Thesis, M.I.T., 1943.

C. Kojabashian, USA

845. Numachi, F., Review of sixty years of fluid mechanics in Japan, *Sci. Rep. Res. Inst., Tohoku Univ., Japan (B),* **11,** 249–263, 1959/1960.

Compressible Flow (Continuum and Noncontinuum Flow)

(See also Revs. 595, 838, 870, 873, 877, 878, 879, 880, 892, 903, 904, 908, 909, 943, 952, 966, 1014, 1051, 1089, 1097, 1149)

Book—846. Pai, S.-I., Introduction to the theory of compressible flow, Princeton, New Jersey, D. Van Nostrand Co., Inc., 1959, 385 pp.

As the author himself states, the purpose of this book is to give a theoretical introduction to the theory of compressible flow. This book is of use especially for students of mathematics and mechanics or of aeronautical engineering who are eager to acquire fundamental knowledge necessary to a further specialization in problems of gasdynamics and high-speed aerodynamics. This didactic purpose is obvious when we notice the author's care for the systematic presentation of the principal notions, of the fundamental assumptions, of various theories of compressible flows and of various methods of solving the problems of the investigated fields. At the beginning of each chapter there is an introductory paragraph indicating the contents of the respective chapter, the new aspect of the phenomenon to be studied, and other interesting commentaries concerning the subject being brought out; this also is a positive didactic aspect of the book since, in this way, the future graduate and research worker can better grasp the various aspects of the physical phenomenon and may develop a critical view so necessary to research work.

In the first two chapters, fundamental notions and gas properties are presented. Beginning with the Chapter III and continuing through Chapter XIV, the fluid is considered inviscid. The one-dimensional flows, steady and nonsteady, with heat addition are treated, the author thus having the possibility of introducing new notions characteristic of compressible flow. Then the author discusses the shock wave, inserting considerations upon the thickness of shock waves, the effects of relaxation time, effects of dissociation and ionization, the reflections of shock waves from solid boundary, the influence of heat addition, giving as examples the condensation wave and the detonation wave. Although the shock wave is briefly presented, the reader can grasp the essential complex aspects of the phenomenon.

In chapter V the author presents the equations and theorems which govern three-dimensional motions, and in the next chapters he discusses various methods of solving the flow equations, namely: the method of small disturbances, the hodograph method, the exact method of solution, the method of characteristics, etc. In chapter XIV the rotational flow of inviscid compressible fluid under its complex aspects is studied. In this last chapter, notions, fundamental equations and assumptions and some essential problems of the magnetogasdynamics field are dealt with, a field in which the author performed various investigations and tried to clear up some ideas.

Then the author, well-known for his works on the theory of the flows of viscous fluids, laminar and turbulent, introduces in Chapters XV and XVI the effects due to viscosity and to heat transfer on the whole scale of the velocity of fluids, bringing out the results obtained in this domain.

The author presents many essential aspects of the flows of compressible fluids, beginning with the classical ones and ending with the up-to-date ones, among which the interaction of the compressible flow field with other physical phenomena is included.

The fact that some of the chapters of the book appear somewhat unequal and not very closely linked does not diminish the value of the book.

Due to the richness and diversity of the contents, this book may be useful to anyone who wishes to learn about the phenomena which take place in the field of compressible flows.

The ample bibliography at the end of each chapter may also be useful for enriching knowledge in this scientific domain.

E. Carafoli, Roumania

847. Schmeer, J. W., Salters, L. B., Jr., and Cassetti, M. D., Transonic performance characteristics of several jet noise suppressors, NASA TN D-388, 48 pp., July 1960.

This paper describes the experimental technique and results of an investigation of the transonic performance characteristics of several noise-suppressor configurations at Mach number from 0.70 to 0.95–1.05. The aim of the investigation was to evaluate the relative performance penalties of several noise-suppressors with hot-jet exhaust. Given are the geometrical shapes, profile characteristics, drawings and photos of the suppressor, which are of undoubted value to those engaged in jet engine design and noise research.

G. A. Tokaty, England

848. Spreiter, J. R., and Alksne, Alberta Y., Slender-body theory based on approximate solution of the transonic flow equation, NASA TR R-2, 54 pp., 1959.

Approximate solutions of the nonlinear equations of the small disturbance theory of transonic flow are found for the pressure distribution on pointed slender bodies of revolution in flight at zero angle of attack at high subsonic Mach numbers, at low supersonic Mach numbers, and at Mach numbers near unity. These results are obtained by application of a method based on local linearization that was introduced recently by the present authors in the analysis of similar problems in two-dimensional flows. The theory is developed for bodies of arbitrary shape, and specific results are given for cone-cylinders and for parabolic-arc bodies at zero angle of attack. All results are compared extensively either with existing theoretical results or with experimental data.

The results of the present paper are of interest not only because of the frequent use of bodies of revolution in practical applications but also because knowledge of the aerodynamic properties of a body of revolution in axisymmetric flow taken together with the transonic area rule and equivalence rule permits the ready calculation of the aerodynamic properties of a wide class of wings, bodies, wing-body combinations, etc., having the same longitudinal distribution of cross-sectional area as the body of revolution.

S. Tomotika, Japan

849. Bragg, S. L., Effect of compressibility on the discharge coefficient of orifices and convergent nozzles, *J. Mech. Engng. Sci., Lond.* **2**, 1, 35–44, Mar. 1960.

In a paper of D. A. Jobson [AMR **10** (1957), Rev. 265] a method was presented by which the variation of discharge coefficient with pressure ratio on sharp edge orifices could be calculated. The present paper extends this procedure for the case when the upstream velocity pattern is affected by compressibility. This is mainly true for high discharge coefficients and if the pressure ratio is near the critical. The new results give the correct figures for the perfect nozzle and for the Borda mouthpiece. Experimental results of various sources are in good agreement at pressure ratios up to the critical. It should be mentioned that the present method enables only to predict the variation of the discharge coefficient but not to calculate the real value for a certain discharge geometry.

N. Scholz, Germany

850. Mack, L. M., The compressible viscous heat-conducting vortex, *J. Fluid Mech.* **8**, 2, 284–292, June 1960.

The plane, steady, laminar vortex flow of a viscous, heat-conducting perfect gas is treated. Simple relations are obtained for the flow quantities in the irrotational vortex for arbitrary Prandtl numbers. When the Prandtl number is 1/2, the irrotational vortex is also isentropic. When the temperature dependence of the viscosity coefficient is taken into account, the vortex flow is rotational. An exact solution for the rotational vortex is obtained.

From author's summary by S. I. Pai, USA

Book—851. Dorfner, K.-R., Three-dimensional supersonic problems in gas dynamics [Dreidimensionale Uberschallprobleme der Gasdynamik], Berlin, Springer-Verlag, 1957, 150 pp. DM 26.

In this work, the author presents various methods used in the study of supersonic flows within the framework of the small disturbance theory. The book includes four chapters.

In the first chapter, the fundamentals of the linearized theory under the assumption of small disturbances, the linearized boundary conditions for wings as well as their aerodynamic characteristics are dealt with. The definition and the computation rules of the generalized functions, denoted by the author as *V* functions, are also introduced in this chapter.

Fields of general supersonic flows around wings of arbitrary planform within the linearized theory are dealt with in the second chapter. The author presents the general problems of the lifting wing with given incidence or given pressure distribution, the wings having an arbitrary planform.

In the third chapter, flows with conical symmetry are dealt with, in conformity with Busemann's and Germain's works. The triangular, rectangular, trapezoidal wings are thus studied in the case of conical flow (homogeneous of the order one).

The general formulas of the high-order homogeneous flow are given in the fourth chapter, being treated according to several authors' works. As an application, the problems of the wing moving with constant angular velocity around a certain axis are solved. In this chapter the high-order homogeneous flow around the wing with subsonic edges is studied by means of the method of singularities.

The author has presented some methods for the study of the steady supersonic flows around thin bodies, at small incidences. The book is of use to those who are eager to know various methods of solving some problems of three-dimensional supersonic flows, especially as far as the application of the "distribution theory" is concerned.

S. Sandulescu, Roumania

852. Grozdovskii, G. L., Supersonic axisymmetric conical flows with conical shocks adjacent to uniform parallel flows, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **23,** 2, 532-538, 1959. (Pergamon Press, Inc., 122 E. 55th St., New York 22, N. Y.)

Author studies all possible cases of supersonic conical flow bounded by a conical shock wave and a uniform stream. From examination of the second-order differential equation of Busemann for the streamlines in the hodograph plane and the singularities of this equation, he concludes there are only four such flows. Reviewer agrees with author that two of these flows which correspond to a converging stream behind a conical shock and a diverging stream ahead of a conical shock appear to be new. Both of their hodograph curves lie within the shock polar or strophoid, forming "inside" rather than "outside" apple curves. Tables for five flow conditions are given, together with an illustration of an interesting supersonic inlet application.

D. E. Ordway, USA

853. Voellmy, H. R., Experimental investigation of different strongly convergent slender rotational bodies at moderately high supersonic speeds (in German), ETH Mitt. Inst. Aero., Zurich, no. 24, 82 pp., 1958.

Author reports on experiments at Mach numbers 1.38 and 1.67 performed in the 40-by-40-cm Zurich wind tunnel with a family of five slender axisymmetric bodies differing only in the shaping of their rear parts. Forces were measured by a strain gage placed inside the models. For one of the bodies, previously used in subsonic experiments, pressure measurements were added.

Chief aim was the comparison of experimental results with theoretical predictions based on linearized potential theory (as well as slender-body theory) or, as the failure of potential theory to explain the observed lifting forces on slender bodies is well known, to contribute to the important problem of elaborating a better suited "model" where viscous effects and resulting flow separation are taken account of. Author does not actually propose a better model, he merely puts the facts before the reader.

Since the Reynolds number based on the length of the models was only about 1.2×10^6, while the shaping of the convergent rear part of the models introduced even a discontinuity in the curvature, the viscous effects due to separation were particularly strong. Therefore it is not surprising that by simply adding the displacement thickness of the calculated boundary layer to the geometrical radius no improvement of potential theory was realized. Equally, by adding to the normal force a cross-flow drag-term taken from measurements on cylinders, no real improvement was achieved. Finally, the refinement which consists in using a non-stationary drag coefficient, while moderately successful for greater incidences, failed completely for small ones. Author concludes that all cruder ways of accounting for flow separation are not really helpful and that a substantial effort is still needed in this field.

A. Von Baranoff, Germany

854. Beheim, M. A., Flow in the base region of axisymmetric and two-dimensional configurations, NASA TR R-77, 57 pp., 1960.

A theoretical and experimental investigation has been conducted of the pressure distribution on the surface of either a circular cylinder or a truncated cone located within the base region of another circular cylinder at Mach number 2. A similar analysis of pressure distribution was made for rearward-facing two-dimensional steps, and theoretical results were compared with experimental results of earlier investigations. Effects of base bleed were also studied with the axisymmetric configurations.

From author's summary

Book—855. Collar, A. R., and Tinkler, J., editors, Hypersonic flow (Proceedings of the Eleventh Symposium of the Colston Research Society, University of Bristol, April 6-8, 1959); New York, Academic Press, Inc., 1960, xv + 432 pp. $13.50.

The following papers were presented at the symposium:

1. B. D. Henshall—Experimental results from the N.P.L. Hypersonic Shock Tunnel.
2. R. K. Lobb—Hypersonic research at the Naval Ordnance Laboratory.
3. K. N. C. Bray, L. Pennelegion and R. A. East—Performance studies for the University of Southampton Hypersonic Gun Tunnel.
4. R. N. Cox—Recent hyperballistics research at ARDE—The ARDE gun tunnels and some experimental studies of hypersonic flow.
5. D. A. Spence and B. A. Woods—Boundary layer and combustion effects in shock tube flows.
6. J. W. Miles—Unsteady flow at hypersonic speeds.
7. H. Oertel—Hypersonic research at the LRSL, Saint Louis.
8. K. W. Mangler—The calculation of the flow field between a blunt body and the bow wave.
9. M. D. Van Dyke—Some numerical solutions in hypersonic flow.
10. J. P. Guiraud—Newtonian flow over a surface—theory and application.
11. D. L. Schultz—Shock tube research at the National Physical Laboratory on the properties of gases at high temperatures. Part I, Ionization measurements.
12. K. C. Lapworth—Shock tube research at the National Physical Laboratory on the properties of gases at high temperatures. Part II, Preliminary spectrographic measurements.
13. H. Metcalfe—Some aspects of the design of hypersonic vehicles.
14. A. J. Eggers, Jr.—Some considerations of aircraft configurations suitable for long-range hypersonic flight.
15. R. R. Jamison—Hypersonic air breathing engines.

Papers 1, 2, 3, 4, 7, 11 and 12 present a thorough discussion of the development of facilities and experimental technique for hypersonic testing. Shock tube, shock tunnel, gun tunnel and ballistic range are discussed and significant results which are obtained in these facilities are presented.

Aspects of the hypersonic flow theories are presented in papers 5, 6, 8, 9 and 10 and design of hypersonic vehicles in 13, 14 and 15. The quality and scope of the papers make this collection a valuable contribution to hypersonic flow research.

J. Rabinowicz, Israel

856. Van Hise, V., Analytic study of induced pressure on long bodies of revolution with varying nose bluntness at hypersonic speeds, NASA TR R-78, 37 pp., 1960.

Pressure distributions and shock shapes for a series of cylindrical afterbodies having nose fineness ratios from 0.4 to 4 have been calculated by using the method of characteristics for a perfect gas. The fluid mediums investigated were air and helium and the Mach number range was from 5 to 40. Flow parameters obtained from blast-wave theory give good correlations of blunt-nose induced pressures and shock shapes. Experimental results are found to be in good agreement with the characteristic calculations. The concept of hypersonic similitude enables good correlation of the results with respect to body shape, Mach number, and ratio of specific heats. From author's summary

857. Gubanov, A. I., Reflection and refraction of shock waves at the interface between two media, Part I, Case of normal incidence, *Soviet Phys.-Tech. Phys.* **3**, 9, 1869–1874, Apr. 1959. (Translation of *Zh. Tekh. Fiz., Akad. Nauk SSSR* **28**, 9, 2035–2040, Sept. 1958 by Amer. Inst. Phys., Inc., New York, N. Y.)

A general equation is obtained from which can be found the pressure in the reflected shock wave when a plane shock wave is normally incident on a plane interface between two arbitrary media. This equation is solved approximately for the case of two ideal gases, for shock waves of small intensity, for media which are only slightly different, and for media that are decidedly different.

From the author's summary by J. N. Aguirre, Argentina

858. Gubanov, A. I., Reflection and refraction of shock waves at the interface between two media, Part II, Regular reflection for oblique incidence, *Soviet Phys.-Tech. Phys.* **4**, 5, 549–557, Nov. 1959. (Translation of *Zh. Tekh. Fiz. Akad. Nauk SSSR* **29**, 5, 615–625, May 1959 by Amer. Inst. Phys., Inc., New York, N.Y.).

Author obtains the general equation from which may be found the pressure in the reflected shock wave when an oblique plane wave is incident on a plane boundary separating two arbitrary media. When there is either a small or a large difference in the two media, this equation can be solved approximately for the case of a shock wave of small magnitude.

From author's summary by J. N. Aguirre, Argentina

859. Friedman, M. P., An improved perturbation theory for shock waves propagating through non-uniform regions, *J. Fluid Mech.* **8**, 2, 193–209, June 1960.

By retaining appropriate nonlinear terms of the flow equations, a solution is obtained which holds for all conditions behind the shock, and reduces to the linearized solution for conditions away from sonic.

The behavior of supersonic or subsonic flow entering regions of expanding or contracting area charges is discussed.

From author's summary by S. I. Pai, USA

860. Glass, I. I., and Heuckroth, L. E., An experimental investigation of the head-on collision of spherical shock waves, Univ. Toronto, Inst. Aerophys. Rep. 59, 111 pp., May 1960.

A detailed experimental investigation was made of the head-on collision of spherical shock waves and their associated flows. The shock waves were produced from the blasts of two 2-inch diameter glass spheres whose centers were located nine inches apart. The spheres were filled with air or helium up to 500 psi and then shattered with a mechanical breaker at a predetermined pressure. The spherical shock waves utilized in the present experiments at the point of collision were relatively weak, that is, of shock Mach numbers $M_s < 1.5$.

Optical techniques were used to record the properties of the flow. These included schlieren wave-speed records of the time-distance plane, instantaneous-spark shadowgraphs, and multi-spark schlieren photographs with equivalent framing rates up to 50,900 pictures per second.

An analytical or numerical solution of this problem is as yet not available owing to the asymmetry of the flow following the collision. The asymmetry introduces a mathematical difficulty that requires the addition of a new space variable and new boundary conditions involving regular and Mach reflection. Consequently, the comparison of theory and experiment was limited to the immediate vicinity of the point of collision. Here, planar wave theory can be used and this problem was solved in detail with the aid of an I.B.M. 650 computer.

The agreement of theory and experiment in this region is quite reasonable considering the limitations imposed by the accuracy of obtaining velocity measurements of the attenuating colliding and receding shock waves at the point of impingement, and the use of relatively weak colliding shock waves.

From authors' summary

861. Saenger, R. A., and Hudson, G. E., Periodic shock waves in resonating gas columns, *J. Acoust. Soc. Amer.* **32**, 8, 961–970, Aug. 1960.

When an oscillating piston forces the enclosed gas in a Kundt tube to vibrate with a finite amplitude near an acoustic resonance frequency of the gas column, shock waves are generated which travel periodically back and forth in the tube. There is also heating of the gas and a rise in its mean pressure. In this paper a theory of the steady-state motion of the gas in its "fundamental" mode has been devised which includes the dissipative effects of wall friction and heat conduction to the tube walls. The dependence of shock strength, mean temperature, and mean pressure on piston amplitude, tube length, gas viscosity, and heat conductivity predicted by the theory are in good qualitative agreement with the small number of experimental data available at present.

From authors' summary

862. System measures shock-front velocities, *Electronics* **33**, 45, 78–81, Nov. 1960.

863. Sichel, M., Higher-order corrections to Taylor's solution for weak, normal, shock waves, *J. Aero/Space Sci.* **27**, 8, 635–636 (Readers' Forum), Aug. 1960.

864. Berndt, S. B., On the propagation of sound in a Prandtl-Meyer expansion (in English), 9th Congrès Intern. Mêcan. Appl., Univ. Bruxelles, 1957; **II**, 178–185.

After stressing the importance of solving the problem of wave propagation in the Prandtl-Meyer expansion when calculating the lift distribution over a double-wedge airfoil of finite thickness performing small harmonic oscillations, the wave propagation in adjacent regions of uniform flow is briefly considered. If the reflected waves from the leading shock are not taken into account, the perturbation velocity field in the upstream region is irrotational and its potential satisfies a linear differential equation. Solutions of the same type can be used for the downstream region of the uniform flow, too. For the perturbation velocity potential in the Prandtl-Meyer expansion region a linear approximation in the form of a partial differential equation is derived, provided the basic steady velocity field is isentropic. By a suitable change of

both independent variables the equation is transformed so that its solutions can be matched directly with the perturbation potential of both adjacent regions of uniform flow. By applying the Laplace transformation to the above equation a partial first-order linear differential equation is obtained and the computational procedure involves the repeated solution of two ordinary differential equations with given initial values. For low-frequency oscillations a polynomial approximation of a function determining the perturbation velocity potential can be assumed and it is shown that this approximation can be obtained in a closed form.

A. Kuhelj, Yugoslavia

865. Jarre, G., Effects of air dissociation and ionization at hypersonic speed, AFOSR TR 59-119 (Lab. Meccanica Applicata Politecn. Torino TN 14), 35 pp., July 1959.

Paper is concerned with two problems: the flow behind a normal shock wave, and the flow at the surface of an insulated flat plate. The equilibrium states are computed with the assumption that oxygen dissociation, nitrogen dissociation, and ionization occur separately, and that oxygen-nitrogen reactions can be neglected. Composition charts and enthalpy-temperature charts are presented for air up to 15,000°K and at several pressures. The charts are applied directly to the two flows with the further assumption that both are isobaric and isenthalpic. The relaxation process is treated for oxygen dissociation only. Wigner's theory is used for the value of the recombination rate. The flat-plate flow is restricted to a laminar boundary layer, but several additional assumptions are needed to arrive at a solution. Simple results are obtained for the degree of dissociation as a function of distance.

L. Mack, USA

866. Patterson, G. N., Recent trends in the mechanics of highly rarefied gases, AFOSR TN 59-790 (Univ. Toronto, Inst. Aerophys. Rep. no. 16), 39 pp., Jan. 1960.

A review of some recent investigations in the flow of highly rarefied gases is presented. The basic nature of the transport process in free molecule flow is deduced from the Boltzmann equation for the molecular velocity distribution function. The present semi empirical state of our knowledge of the reflection of molecules from the surface of a solid is summarized and some directions for research are indicated. The aerodynamic properties of bodies in highly rarefied flows is considered with emphasis on the long cylinder as a case of special interest. The theory is extrapolated to the limit of very high-speed ratios or Mach numbers and the results are compared with those deduced from the Newtonian flow theory. The application of recent studies of rarefied gas flows to the development of instruments for the measurement of the pressure, temperature and density of such flows is reviewed in some detail. The use of free molecule probes for the study of boundary layers and shock waves is outlined. The review is brought to a close with a very brief consideration of some factors involved in the collision-free flow of a plasma.

From author's summary

867. Mickley, H. S., and Turano, A., Jr., Rarefaction effects in low-speed turbulence, *J. Aero/Space Sci.* **27,** 8, 629-630 (Readers' Forum), Aug. 1960.

868. Palosh, M. M., Supersonic diffuser with small angle near the throat (in Russian), *Rev. Mech. Appl.* **4,** 3, 417-428, 1959.

Analytical functions for determination of a contour of supersonic diffuser to give steady, uniform and parallel flow are derived and presented in a form of charts and tables. The method is an improvement on that given by A. O. L. Atkin in "Two-dimensional supersonic channel" Aero. Res. Counc., Lond., R and M 2174, part 1.

A. N. Petroff, USA

869. Eichacker, Suzanne S., and Hoge, H. J., Jet-compressor efficiencies as influenced by the nature of the driving and driven gases, *J. Aero/Space Sci.* **27,** 8, 636-637 (Readers' Forum), Aug. 1960.

Boundary Layer

(See also Revs. 654, 837, 853, 881, 888, 889, 899, 902, 980, 988, 995, 999, 1009, 1014, 1015, 1018, 1027, 1054, 1060, 1153, 1154)

Book—870. Landau, L. D., and Lifshitz, E. M., Fluid mechanics (Course of Theoretical Physics, Vol. 6), (Translated from the Russian by J. B. Sykes and W. H. Reid), Reading, Mass., Addison-Wesley Publishing Co., Inc., 1959, xii + 536 pp. $14.50.

An idea of the scope of this work can be gained from the chapter headings: Ideal fluids; Viscous fluids; Turbulence; Boundary layers; Thermal conduction in fluids; Diffusion; Surface phenomena; Sound; Shock waves; One-dimensional gas flow; Intersection of surfaces of discontinuity; Two-dimensional gas flow; Flow past finite bodies; Fluid dynamics of combustion; Relativistic fluid dynamics; Dynamics of superfluids; Fluctuations in fluid dynamics.

The authors succeed in giving a very satisfactory account of this extensive material in one volume of reasonable size by adhering rather strictly to the point of view of a theoretical physicist. Basic ideas and fundamental problems are given a concise but general and, with a few exceptions, essentially rather complete treatment. Some pertinent particular problems are worked out in more detail. Solutions of these problems are given in small print; these insertions contain a large amount of very interesting material. Very little attention is paid to those aspects of fluid dynamics which appeal more to the engineer or applied mathematician, e.g. wing theory. The chapter on turbulence, a phenomenon somewhat uncongenial to a physicist prone to deductive methods, is not quite up to the standard of the remainder of the book. It is rather surprising that nothing is said about magnetohydrodynamics. This might be caused by the fact that the present translation is from a not very recent (exact year is not stated) Russian edition, presumably written before the present boom in this subject.

Reviewer was dissatisfied with only one aspect of this otherwise excellent and valuable book, namely the references, or rather the lack of them. Only a very few complete references are given. More often only the name of an author (sometimes with the year of publication) is given after stating a result, but even these occasions are not nearly as numerous as the references in the usual books of this type. Classical results such as Prandtl-Meyer and Taylor-McColl flows remain anonymous.

L. J. F. Broer, Holland

871. Acrivos, A., Shah, M. J., and Petersen, E. E., Momentum and heat transfer in laminar boundary-layer flows of non-Newtonian fluids past external surfaces, *AIChE J.* **6,** 2, 312-317, June 1960.

The drag and rate of heat transfer from an isothermal surface are computed for a power-law fluid having properties which are not dependent on temperature. Inspectional analysis of the modified boundary-layer equations yields a general relationship for the drag coefficient and the Nusselt numbers as functions of the generalized Reynolds and Prandtl numbers. Detailed study of the flow past a flat plate employed both Blasius type of similarity transformation and the momentun integral method of Pohlhausen. It was found that the integral method is not as accurate for non-Newtonian fluids as it is for Newtonian fluids.

E. H. Wissler, USA

872. Faulders, C. R., Reynolds-analogy parameter for the laminar boundary layer with blowing, Pr = 3/4, *J. Aero/Space Sci.* **27,** 8, 628-629 (Readers' Forum), Aug. 1960.

873. Stalker, R. J. Sweepback effects in turbulent boundary-layer shock-wave interaction, *J. Aero/Space Sci.* **27,** 5, 348–356, May 1960.

Author carried out experiments in a 6 × 3-in. intermittent blow-down-type wind tunnel at M = 2.36 and a Reynolds number of 9×10^6 per in. The tested sweptback configurations were: (a) a step attached to a rotatable steel plate at the test section on the sidewall of the tunnel, (b) a flat plate with leading edge swept at 45°, mounted in the test section having steps with upstream face parallel to the leading edge, (c) a wooden ramp attached to one of the contoured nozzle liners, generating an ordinary two-dimensional oblique shock which interacts with the boundary layer on a sidewall of the test section, and (d) a plate of uniform thickness on the tunnel sidewall, extended from the subsonic portion of the nozzle to the test section which formed a sweptback step for studying the reattaching flow. The angles and heights of the steps were varied, the pressures at various points were measured, and boundary-layer traverses were made.

The essential conclusion to be drawn from the experimental results is that the influence of the cross flow is negligible for moderate sweep angles. Accordingly the main characteristics of the boundary-layer shock-wave interaction, i.e., peak pressure rise, upstream influence and reattaching flow, may be treated with the aid of the two-dimensional theory (Crocco-Probstein, Lighthill, Chapman-Korst) by introducing the normal component of upstream Mach number. S. Savulescu, Roumania

874. Cox, R. G., and Bauer, F. L., Boundary layer stimulation in rectangular conduits, *Proc. Amer. Soc. Civ. Engrs.* **86,** HY 2 (*J. Hydr. Div.*), 25–38, Feb. 1960.

The effect on the flow of water in a rectangular conduit of roughness elements (cubes) on the walls at the inlet has been investigated. Distance required for fully developed turbulent flow is found to decrease with increasing size of roughness elements. With roughness elements, fully developed turbulent flow is established at about 40 equivalent diameters; without, at about 50 equivalent diameters. Pressure gradient on the other hand, according to the authors, indicates fully developed flow at 30 diameters. Free-stream turbulence level, which is usually a pertinent parameter in problems of this kind, has not been reported.

Authors are of the mistaken impression that pipe flow above a Reynolds number of 3000 is always turbulent. Laminar pipe flow has been shown to exist for Reynolds numbers as high as 50,000 [e.g. Ekman, V. W., *Ark. Mat., Astron., Fysik, Stockholm* **6,** 1910]. Transition Reynolds number for fully developed laminar pipe flow depends on the magnitude of superimposed disturbance [Keuthe, A. M., and K. R. Raman, "Some details of the transition to turbulent flow in Poiseuille flow in a tube," University of Michigan, Dept. Aeronaut. and Astronaut. Engng., AFOSR TR 59-84, June 1959]. S. K. F. Karlsson, Sweden

875. Bradshaw, P., Approximate solution of the "inverse problem" of boundary layer theory, *J. Roy. Aero. Soc.* **64,** 592, 225–226 (Tech. Notes), Apr. 1960.

Author uses existing integral formulas for the thickness of laminar and turbulent boundary layers to derive a useful method of calculating the free-stream velocity distribution to a given variation of shape parameter. The method is applied on the design of an airfoil which just avoids laminar separation up to the trailing edge by taking a shape parameter $(\theta^2/\nu)(du/dx) = \lambda = 0.075 - 0.175\,x$. The simple solution is $u \sim x\,(x + 0.171)^{-7/3}$.

F. W. Riegels, Germany

876. Tatsumi, T., and Gotoh, K., The stability of free boundary layers between two uniform streams, *J. Fluid Mech.* **7,** 3, 433–441, Mar. 1960.

Hydrodynamic stability of free boundary-layer flows is treated in general. It is found that the situations at low Reynolds numbers are universal for all velocity profiles of free boundary-layer type. Curves of constant amplification are calculated as far as $0(R^3)$. In particular, the asymptotic form of the neutral curves for $R \doteq 0$ is found to be $\alpha = R/(4\sqrt{3})$, so that the critical Reynolds numbers of these flows are identically zero. The phase velocity of the disturbance is also found to be zero, for all disturbances, up to the second approximation.

A method of normalizing the velocity profiles is suggested, and existing results for the stability of various profiles at large Reynolds numbers are discussed from a new point of view.

From authors' summary by H. G. Lew, USA

877. Creager, M. O., Effect of leading-edge thickness on the flow over a flat plate at a Mach number of 5.7, NASA TN D-313, 31 pp., May 1960.

The flow over blunt flat plates varying in thickness from 0.001 to 0.25 in., at a free-stream Reynolds number of 20,000 per in., was surveyed by means of a total pressure traversing probe and of surface static pressure measurements. The boundary-layer limit line and shock-wave shape were determined. For the thinnest plates, the boundary layer was found to grow linearly. The growth of the boundary layer in a high entropy layer could be investigated only for the thickest plates. Comparison of measured quantities with existing theories is unsatisfactory; therefore, as author himself stresses, the extension of the research for a more detailed determination of the flow pattern in the proximity of the leading edge is desirable. A more consistent physical model of the flow, and also a better understanding of hypersonic boundary-layer phenomena, might thus be developed.

L. Z. Dumitrescu, Roumania

878. Herring, T. K., The boundary layer near the stagnation point in hypersonic flow past a sphere, *J. Fluid Mech.* **7,** 2, 257–272, Feb. 1960.

Flow properties behind shock waves caused by bluff bodies traveling at supersonic speeds are of major importance in missile and high-speed aircraft design. Paper presents a mathematical solution for the laminar boundary layer near the stagnation point of a sphere. Surface temperature is free-stream static and shock is strong. Air is assumed calorically and thermally perfect with a Prandtl number of 0.72 and a dynamic viscosity directly proportional to temperature.

Based on work of Homann [*ZAMM* **16,** p. 153, 1936] and Lighthill [*J. Fluid Mech.* **2,** 1957, 1], author reduces problem to two ordinary simultaneous differential equations for the velocity and temperature profiles. These are solved by numerical integration along a normal to the surface using a digital computer. Results are presented as functions of free-stream Mach number, M_∞, Reynolds number, R_∞ and specific heat ratio. As R_∞ increases, boundary-layer thickness is shown to decrease while shock stand-off distance increases. Stand-off distance also decreases with increasing M_∞ and decreasing specific heat. For constant M_∞ and specific heat ratio, the product of skin-friction coefficient and the square root of R_∞ decreases with increasing R_∞, only approaching a constant value at R_∞ greater than 10,000.

Reviewer's comment is concerned with the perfect gas assumption for air. Author suggests that the effects of dissociation on flow properties are accounted for by a proper choice of specific heat ratio. A consideration of the kinetics of chemical reaction in the cooled boundary layer emphasizes the oversimplification of this approach. The effect on transport properties could have been approximated in present analysis by changing the Prandtl number to one more representative of the existing pressures and temperatures. H. E. Brandmaier, USA

879. Lilley, G. M., A simplified theory of skin friction and heat transfer for a compressible laminar boundary layer, Coll. Aero., Cranfield, Note 93, 76 pp., Jan. 1959.

The compressible laminar boundary-layer equations for a perfect gas in steady flow at arbitrary external Mach number and wall temperature distribution are solved approximately by the combined use of the Stewartson-Illingworth transformation and application of Lighthill's method to yield the skin friction and rate of heat transfer. From author's summary by W. T. Snyder, USA

880. Lighthill, M. J., Dynamics of a dissociating gas: Part 2, Quasi-equilibrium transfer theory, *J. Fluid Mech.* **8,** 2, 161–182, June 1960.

The title very clearly indicates the material to be discussed. The transport processes are divided into usual transport of mass momentum and energy, including the transport of ionization and dissociation energies, and into several sections on radiative transport.

This work, in the opinion of the reviewer, should be called to the attention of all high-speed aerodynamicists because of the useful approximations that are offered. It should be noted that Lighthill's suggestion that thermal diffusion can be neglected in the heat transfer seems to be well founded (section 7); however, it is likely that the recovery factor is somewhat more sensitive to the thermal diffusion. The last sections on radiative transport present a good summary for the aerodynamacist.

E. E. Covert, USA

881. Chung, P. M., and Anderson, A. D., Surface recombination in the frozen compressible flow of a dissociated diatomic gas past a catalytic flat plate, *ARS J.* **30,** 3, 262–264 (Tech. Notes), Mar. 1960.

882. Becker, E., Unsteady boundary layers behind shock and expansion waves (in German), *Z. Flugwiss.* **7,** 3, 61–73, Mar. 1959.

Author summarizes existing solutions for the laminar and turbulent boundary-layer development behind a shock or expansion wave traveling along a plane wall at approximately constant speed. These solutions are applicable to the flow in a shock tube or in a so-called tube wind tunnel. The flow behind waves through which the properties change discontinuously as well as the flow behind continuous wave systems is discussed for both the weak wave and the strong wave limit. For laminar flow, a perfect gas with constant Prandtl number and constant specific heat is assumed. A comparison of some of the features of the analytical results with experiment is presented. A. Kistler, USA

883. Gupta, A. S., Effect of buoyancy forces on certain viscous flows with suction, *Appl. Scient. Res.* (*A*) **8,** 4, 309–320, 1959.

First part of paper studies the effect of gravity on the unsteady flow of a viscous incompressible fluid due to the motion of an inclined infinite flat plate along its line of greatest slope. The plate is supposed to be porous and suction is applied. Two cases are treated: (1) constant wall suction velocity and plate velocity proportional to e^{ct}, (2) wall suction velocity inversely proportional to the square root of time for the uniformly accelerated plate. (Without suction this problem has been treated by C. R. Illingworth, *Proc. Camb. Phil. Soc.* **46,** p. 603, 1950 [AMR **4** (1951), Rev. 1260] for a compressible fluid.) By integrating the boundary-layer equations explicit expressions for velocity and temperature distribution are given in both cases for any Prandtl number. In case (2) the velocity in the boundary layer increases with increasing Grashof number and the skin friction at the plate is proportional to the square root of time.

Second part of the paper studies the free convection flow of a compressible fluid past an infinite flat and porous plate subjected to suction and making an angle with the horizontal. Taking approximately thermal conductivity proportional to temperature it is found that the skin friction at the plate increases with gravity and decreases with suction.

H. Behrbohm, Sweden

884. Holman, J. P., Stout, K. E., and Soehngen, E. E., On the effects of flow obstructions on free-convection boundary-layer oscillations, *J. Aero/Space Sci.* **27,** 6, 463–464 (Readers' Forum), June 1960.

885. Zaitsev, A. A., The stability of a viscous layer on a solid body in a flow of gas, *Soviet Phys.-Doklady* **5,** 1, 49–53, July/Aug. 1960. (Translation of *Doklady Akad. Nauk SSSR* (*N.S.*) **130,** 6, 1228–1231, Jan./Feb. 1960 by Amer. Inst. Phys., Inc., New York, N.Y.)

886. Ostrach, S., Goldstein, A. W., and Hamman, J., The effect of a deceleration force on a melting boundary layer, *J. Aero/Space Sci.* **27,** 8, 626–627 (Readers' Forum), Aug. 1960.

887. Kafarov, V. V., and Dutnerskii, Yu. I., An equation for the calculation of the boundary velocities of flows in extraction columns (in Russian), *Zh. Prikl. Khim.* **30,** 11, 1698–1701, 1957; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5304.

A relationship is proposed between the boundary velocities of flows, corresponding to the most efficient regimes of mass transfer and extraction columns, and the different physical properties of the phases and characteristics of the fitment, recorded in the form of an equation connecting two dimensionless parameters. The soundness of the equation is confirmed by experimental data from the authors' own work and work taken from the literature. As an example of application of the equation a calculation is furnished for the determination of the diameter of an extraction column for the system benzene-phenol-water solution.

A. M. Brodskii
Courtesy Referativnyi Zhurnal, USSR

Turbulence

(See also Revs. 834, 867, 870, 873, 965, 968, 980, 982, 983)

888. Davydov, B. I., On the statistical dynamics of an incompressible turbulent fluid, *Soviet Phys.-Doklady* **4,** 4, 769–772, Feb. 1960. (Translation of *Doklady Akad. Nauk SSSR* (*N.S.*) **127,** 4, 768–771, July/Aug. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Turbulent flow bounded by solid walls is treated in the manner of Kolmogorov whereby an ensemble of flows is considered, each of which is independent of the others but subjected to the same constraints. The flow of the fluid is then described by a probability distribution of the various hydrodynamic quantities and their corresponding moments determined from the ensemble. The fundamental flow quantities chosen were the mean velocity and mean pressure, the second and the third moments of fluctuating velocities, and the turbulent energy dissipation. The remaining required moments were expressed in terms of those described above. Justification for assumptions is reserved for comparison with experiment. No comparison is given.

R. M. Drake, Jr., USA

889. Davydov, B. I., On the statistical theory of turbulence, *Soviet Phys.-Doklady* **4,** 4, 779–781, Feb. 1960. (Translation of *Doklady Akad. Nauk SSSR* (*N.S.*) **127,** 5, 980–982, July/Aug. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Consideration of the equation developed in earlier paper [see preceding review] as applied to turbulent flow with logarithmic velocity distribution. Experimental results of Laufer [NACA Rept. 1174] for turbulent pipe flow were used to determine the arising empirical constants. Final results are shown in terms of only two empirical dimensionless constants.

R. M. Drake, Jr., USA

890. Szablewski, W., Asymptotic law for the diffusion of turbulence in hot air jets in agitated and static atmospheres (in German), *ZAMM* **39**, 1/2, 50–67, Jan./Feb. 1959.

The velocity and temperature fields of hot air jets both for circular (axisymmetric) and for slit-like (two-dimensional) cross sections are computed far downstream on the basis of Prandtl's equations for free turbulence. The two cases when the surrounding air is at rest and when it has a uniform velocity along the axis of the basic jet are considered. The results for the circular jet are in good agreement with the experimental results. It is interesting to note that the empirical coefficient x_1, appearing in the expression for the eddy viscosity, in the case of a circular jet is practically constant along the line from nozzle to infinity.

S. D. Nigam, India

891. Howard, C. D., and Laurence, J. C., Measurement of screen-size effects on intensity, scale, and spectrum of turbulence in a free subsonic jet, NASA TN D-297, 38 pp., Aug. 1960.

The effects of screens of three different mesh sizes on the intensity, scale, and spectrum of turbulence in the central core of an air jet were measured. The intensity was found to be a linear function of the mesh size within the central core. The spectra of turbulence (power-spectral-density) contain energy peaks in the frequency range of 630 to 800 cps which have been added by vortices shed periodically from the lips of the jet. The scale of the turbulence is altered somewhat by the screens and is a linear function of distance from the nozzle exit.

From authors' summary

Aerodynamics

(See also Revs. 835, 840, 852, 853, 856, 864, 868, 876, 877, 930, 950, 1018, 1051, 1056, 1072, 1073, 1074, 1075, 1076, 1087)

Book—892. Jacob, G., Mathematical introduction to the mechanics of fluids [introduction mathematique a la mécanique des fluides], Bucarest, Editions de l'Academie de la Republique Populaire Roumaine, 1959, 1286 pp. Lei 66.50.

This book gives an extremely mathematical treatment of the field of fluid mechanics. It is written in a very clear style and reminds one of the old French mathematical classics like Goursat and Picard. All proofs and derivations are presented rigorously but also well-ordered so that details in which one is not interested can easily be skipped.

The book consists of five parts: I. Some boundary-value problems, 224 p.; II. Equations of motion, 318 p.; III. Drag in incompressible fluids, 184 p.; IV. Compressible fluids, 242 p.; V. Approximation methods in compressible fluids, 304 p.

The first part deals with Laplace's equation in two dimensions and in particular with the Dirichlet and Neumann problems for the circle and for the annular region between two concentric circles. Also the Riemann problem (in the terminology of Muskhelishvili called the Hilbert Problem) of determining a function, analytic save at a given contour, from a linear relation between its limiting values at both sides of this contour, is considered extensively, both in its general form as well as in a number of special cases.

The second part begins with the fundamental equations for ideal fluids and for viscous fluids. A number of special cases of viscous flows (Poiseuille and Stokes) are considered. A chapter in this part is devoted to d'Alembert's paradox and to the hypotheses under which it holds. Another chapter deals with the determination of the velocity field from a given vortex distribution, both if the fluid is present in the whole space and if it is limited to a finite region. In the last chapter plane flows in incompressible fluids are considered, including the theory of wing sections. Flows with given singularities (point vortices) and flows with distributed vorticity (shear flows) are also considered.

An important section of part 3 deals with Helmholtz' theory concerning the flow behind a bluff body. Solutions are given for a number of cases. The flow around a body placed in a jet and also the jet flow coming out of a body are treated. In the latter case the calculation of the contraction coefficient is important. Furthermore, in this part, Joukowski's theory on the circulation around a wing of infinite span, thin airfoil theory for steady and unsteady flow, as well as the jet flap are treated. Finally, Prandtl's theory for the finite wing is given. However, almost nothing is said on lifting surface theory.

Part 4 begins with the theory of second-order hyperbolic partial differential equations. Then the usual theory of compressible flow is presented, but later chapters of this part are again of unique importance in presenting many applications of hodograph methods. Following work of Chaplygin the author shows how Helmholtz' problem and the free jet problem can also be solved for compressible flow.

The last part considers for subsonic flow the methods of Janzen-Rayleigh, Imai-Lamla and Poggi-Kaplan. In the chapters dealing with supersonic flow much attention is paid to conical flows. Finally, approximation methods for transonic flows are given and investigations of Tricomi, Frankl, Lighthill, Cherry, Tomotika and Tamada as well as those of Morowetz are mentioned.

Summarizing, it may be said that the major part of the book is devoted to plane flows and that in this field the author has succeeded in presenting a very complete text, containing many new or less known results. For three-dimensional flows the book is much less complete; for instance slender-body theory is not treated.

Many references to other investigators are given in all chapters. There are very few printing erros.

A. I. van de Vooren, Holland

893. Miele, A., Lagrange multipliers and quasi-steady flight mechanics, *J. Aero/Space Sci.* **26**, 9, 592–598, Sept. 1959.

Quasi-steady flight mechanics problems for extremum conditions are analyzed by Lagrange multipliers. A solution is obtained in determinantal form for such various optimum conditions of motion as maximum speed, maximum range, etc., for any given aircraft configuration and a given engine satisfying the equations of motion and arbitrary constraints. H. G. Lew, USA

894. Monakhov, N. M., On the computation of the circulation of gliding wing of large span, NASA TT F-31, 11 pp., June 1960. (Translation of *Izvestiia Vyssbikh Uchebnykh Zavedenie, MVO USSR, Seriya Aviatsionnaii Tekbnika* **1**, 19–26, 1958.)

The double integral in the integral equation of the lifting surface theory can be transformed into simple integrals on the given premise of small chord length compared with span of the wing. Moreover, wing sections near the tip are disregarded in this approximation, in which terms up to magnitudes of the second order of chord-span ratio are taken into consideration. The solution of the integral equation shows that the "three-quarter point" method of wing theory is proper with a precision up to the chosen magnitudes of second order of chord-span ratio. Only three Russian references are given. F. W. Keune, Germany

895. Honda, M., Theory of a thin wing in a shear flow, *Proc. Roy. Soc. Lond.* (*A*) **254**, 1278, 372–394, Feb. 1960.

This paper considers an inviscid shear flow past an airfoil spanning two parallel plane walls, under the assumptions of thin airfoil theory and with the boundary condition satisfied at the walls. The free-stream velocity is a function of the coordinate in the spanwise direction normal to the walls. The pressure distribution around the airfoil, the spanwise lift distribution, and the induced drag due to the nonuniformity of the spanwise lift distribution are studied theoretically, with some numerical calculations.

From author's summary by D. W. Dunn, Canada

896. Sheppard, L. M., Experimental evidence on the transonic and supersonic similarity laws for the wave drag of non-lifting wings, Austral. Defense Scient. Service, Weapons Research Establishment TN HSA 54, 17 pp., Nov. 1959.

The report is a systematic rearrangement from the current literature of some derived experimental values of the wave drag of slender wings and wing-body combinations. The investigation shows the first-order similarity law to be useful also for thin wings in those areas where the linearized theory gives poor results. Through the application of the transonic first-order similarity law it is shown that the sonic area rule is valid for slender-wing-body combinations if one of the author's introduced products, wing-span-to-length ratio times the cube root of the thickness-to-chord ratio, is less than unity. K. Fristedt, Sweden

897. Roper, G. M., Drag reduction of thin wings at supersonic speeds, by the use of camber and twist, Aero. Res. Counc. Lond. Rep. Mem. 3132, 79 pp., 1959.

In earlier reports [ARC Rep. Mem. nos. 2794 (1950) and 2865 (1951)] the local distributions due to certain camber distributions of triangular wings were determined, within the scope of linearized small-disturbance theory. Here these distributions and higher-degree camber and twist distributions are used to minimize the drag due to incidence, camber, and twist, for given lift, of (a) triangular wings with subsonic leading edges and unswept trailing edges and (b) sweptback wings with subsonic leading edges and straight supersonic or subsonic trailing edges. Two cases are considered: (1) leading-edge suction included in the optimizing process and (2) leading-edge suction ignored in the optimizing process. For these calculations, one, two, three, or four basic camber-and-twist solutions are combined with that of a flat plate so as to obtain maximum drag reductions for each planform. The results show that appreciable reductions of flat-wing drag can be achieved, especially if suction forces are ignored.

Although 43 "references" are listed, most of them are not referred to, although some were concerned with substantially the same problem (and others appear to have no close relationship to this study). The reviewer notes, for example, that in Reference 33 [Tsien, S. H., AMR **9**(1956), Rev. 3291 and AMR **7**(1954), Rev. 1186] a more limited family of cambers was used, but otherwise the procedure was the same and the results, including both assumptions regarding leading-edge suction, were much the same.

W. R. Sears, USA

898. Stewartson, K., A note on lifting line theory, *Quart. J. Mech. Appl. Math.* **13,** 1, 49–56, Feb. 1960.

This paper, which is primarily a mathematical one, presents a solution of the integrodifferential equation for the spanwise variation of circulation about a lifting line. The case of a wing of semi-infinite span and constant chord is solved by a modified Wiener-Hopf technique. This solution is then used to give, approximately, the lift coefficient on a high-aspect-ratio rectangular wing. The induced drag is also given.

Since the original integral equation is not of the conventional form for a Wiener-Hopf integral, an extension of this technique is required. The first steps in the solution are given without explanation, however, so that the generality of the method is not apparent. In fact, equation 2.6 seems to have a typographical error. A derivative of $f(\alpha, x)$ should appear under the integral.

The solutions for lift and induced drag are compared to the known formulas for elliptically loaded wings. The rectangular wing case contains a logarithmic term. At the high aspect-ratios for which the solution is valid, the rectangular wing lift is a few per cent less than that of the corresponding elliptical wing.

L. H. Schindel, USA

899. Hyde, D., Pressure and boundary layer measurements on a tapered swept wing in flight, Coll. Aero., Cranfield, Rep. 128, 46 pp., Mar. 1960.

Pressure and boundary-layer measurements were made in flight on a full-scale swept half-wing mounted as a dorsal fin on the mid-fuselage of an Avro Lancaster aircraft. A Reynolds number range of 0.88×10^6 to 1.86×10^6 per foot was available. The tapered wing had a semi-span of 102.5 ins. and an aspect ratio of 2.87; the quarter chord sweep was 40° and the symmetrical section was RAE 102, of 8% thickness/chord ratio along wind.

Comprehensive static pressure measurements were recorded over a nominal incidence range of 0° to 10°. At mid-semispan and zero incidence, the measured chordwise pressure distribution compared well with theory. The nondimensional chordwise and spanwise loadings were in close agreement with Kuchemann's predictions, but the experimental lift curve slope was 6% greater than the theoretical value.

From the boundary-layer results the positions of the transition fronts were deduced. No laminar flow was obtained on either surface at the highest Reynolds number of 1.86×10^6 per foot, or at incidences of 6° and greater at all test Reynolds numbers.

The secondary flow Reynolds number corresponding to the onset of sweep instability was found to be in the range $80 < N < 133$; Owen's predicted critical value is 125.

From author's summary

900. Polhamus, E. C., Geller, E. W., and Grunwald, K. J., Pressure and force characteristics of noncircular cylinders as affected by Reynolds number with a method included for determining the potential flow about arbitrary shapes, NASA TR R-46, 78 pp., 1959.

Low-speed pressure distributions and force characteristics of a series of noncircular, two-dimensional cylinders have been measured for a Reynolds number range 0.1×10^6 to 1.0×10^6 and for a number of flow incidences: large Reynolds number effects are evident.

Experimental pressure distributions are compared with theoretical potential theory pressure distributions obtained by conformal transformation to circle; as might be expected, agreement is poor. Authors hope that theoretical pressure distributions may lead to prediction of separation points.

Most interesting experimental results are for square cylinder with rounded corners where side force shows sign reversal with change in Reynolds number.

Authors point out application of work to estimation of side force on fuselage in flat spin. At lower Reynolds number square cylinder shows propelling force in spin.

R. D. Milne, England

901. Bagley, J. A., An estimate of the forces on annular fairings, *J. Roy. Aero. Soc.* **63,** 581, 315–316 (Tech. Notes), May 1959.

Paper describes a simple method for estimating the forces on an annular fairing containing a fan or other device for producing a difference between the velocities of the internal and external flows. Numerical results are included for a range of fairing lengths and velocity ratios. D. W. Holder, England

902. Curle, N., and Skan, Miss S. W., Calculated leading-edge laminar separations from some RAE aerofoils, Aero. Res. Counc. Lond. Curr. Pap. 504, 15 pp. + 5 figs., 1960.

When separation occurs at the leading edge of a thin airfoil, the Reynolds number at separation largely indicates whether a long or short separation bubble is formed. This Reynolds number depends upon the boundary-layer development, which is governed in turn by such parameters as the lift coefficient and the ratio r/c of the nose radius to the airfoil chord. Authors' calculations have been carried out to determine separation conditions, when these parameters are varied, for the RAE 100–104 family of airfoils.

From authors' summary

903. Bugler, J. W., and Hanslip, N. C., Lift and drag of single wedge sections in two dimensional transonic flow, Coll. Aero., Cranfield, Rep. 131, 38 pp., May 1960.

The similarity of the differential equations of the transonic flow of a gas in two dimensions and of the flow of shallow water led to the choice of the latter as an experimental method to determine the pressure distribution, lift and drag on wedges with total angles of 10°, 15° and 20°. The wedges were towed through shallow water and the wave pattern was determined by the measurement of water depth using a photographic technique. The results have been compared with theory and with wind-tunnel experiments. For the 10° and 15° wedges the trends for a range of angles of incidence agree with the predictions from transonic small-disturbance theory, whereas those for the largest wedge of 10° semi-angle indicate that this angle is too large to expect satisfactory experimental results. The trends are also similar to those obtained by other workers in a wind tunnel. From authors' summary

904. Berndt, S. B., A note on the drag due to lift as influenced by a jet flap on a wing of finite span, Flygtek. Forsoksanst. Medd. 85, 10 pp., 1959.

Paper is an extension of classical subsonic wing theory that takes into account effect of a jet flap. Analysis is carried out in the Trefftz plane. Jet flap reduces minimum induced drag as if the aspect ratio had been increased. As in classical theory, minimum drag is obtained for constant down wash in Trefftz plane.

K. G. Guderley, USA

905. Marsden, D. J., and Popock, P. J., An experimental investigation of the deflection of a free-air jet by a flapped wing; the superadditive effects of shielded flow control devices, Nat. Res. Counc., Canada, LR-285, 49 pp., July 1960.

Methods for improving the slipstream deflection effectiveness of a 40-percent chord single-slotted double flap were studied experimentally using a half-wing model mounted in a free-air jet. The tests were conducted out of ground effect.

A porous suction strip over the nose of the fore flap, when shielded on either side of the jet by chordwise fences, increased markedly the slipstream turning effectiveness of the flap. The increase was greater than that due to the sum of the separate effects of porous suction and fences.

The tests indicate that the flapped airfoil with the shielded-suction system would deflect through 90 degrees the slipstream from a propeller with a diameter 0.75 times the wing chord. The suction power required is modest; however, the turning loss would be 30% or less. From authors' summary

906. Graham, M. E., and Ryan, B. M., Trim drag at supersonic speeds of various delta-planform configurations, NASA TN D-425, 98 pp., June 1960.

The drag due to lift and the maximum lift-to-drag ratio at supersonic speeds of zero-thickness, trimmed, statically stable delta-wing-plus-tail, delta-wing-plus-canard, and delta-wing-alone configurations are studied with the aid of linear theory. In general it is found that the drag due to lift decreases and the maximum lift-to-drag ratio increases, the "tail length" increases and the static margin decreases.

From authors' summary by A. N. Petroff, USA

907. Wang, K., and Ting, L., Analytic solutions of planar reentry trajectories with lift and drag, AFOSR TN 60-508 (Polyt. Inst. Brooklyn, Dept. Aero. Engng. Appl. Mech. PIBAL Rep. 601), 67 pp., Apr. 1960.

Extending work of Lees, Hartwig, and Cohen [AMR **13**(1960), Rev. 2415], this report obtains algebraic formulas giving approximation to reentry velocity (V and θ), assuming a shallow trajectory and constant gravitational field but with varying atmospheric densities providing lift as well as drag. Approximate formulas for total acceleration and maximum acceleration are also given. Results are employed in some examples amply illustrated with graphs and tabulations. M. L. Juncosa, USA

908. Clarke, J. H., The forces on wing-fuselage combinations in supersonic flow, *J. Fluid Mech.* **8,** 2, 210-226, June 1960.

Reverse flow relations are used to provide convenient expressions for the aerodynamic forces which act on a general wing-fuselage combination in supersonic flow. Drag, lift, spanwise and chordwise lift distributions, and wing moments are treated. Consideration is given to available methods and results, including tables, which apply to the wing-fuselage interference problem, and reverse-flow relations are then employed to effect desirable changes in the defining force expressions by introducing wings or fuselages in the reverse flow. It is shown that the aerodynamic forces can be determined from a solution for the pressure on only the fuselage surface within the domain of dependence of the wing, this region being selected on the basis of relative ease of computation. In some cases the simplification achieved is quite substantial. Certain results in the literature arise naturally as special cases.

Reverse-flow theorem is re-examined in the light of the procedure considered, and is found to be inapplicable in one respect. Difficulty is circumvented by constructing an acceptable configuration which is equipollent (i.e. configuration constructed to support identical aerodynamic forces) to the prescribed one. It appears that the method given is applicable in other linear hyperbolic problems in mathematical physics when bulk or gross information is required and a suitable reciprocity relation can be constructed.

From author's summary by G. Altmann, Germany

909. Kowalke, F., Aerodynamic stability derivatives of wings at subsonic velocities (in German), Jahrbuch Wissenschaft. Gesellsch. Luftfahrt, 1958, 40-48.

The quasi-steady forces and moments due to angle-of-attack, side-slip, rolling, pitching, yawing, elevator deflection, and aileron deflection are calculated using electronic computer for three wings, using Truckenbrodt's linear lifting-surface theory and Prandtl-Glauert rule. Wings are delta wing and two tapered trapezoidal wings, one with sweepback, one without.

A. E. Bryson, USA

910. Azuma, A., The allocation of the control magnitude for axisymmetrical missile, *Trans. Japan Soc. Aero Space Sci.* **2,** 2, 35-48, 1959.

The problem attacked is to determine the response of spinning, axisymmetric missiles having symmetrical arrangements of control organs to deflections of these organs. First treating the problem statically, for slowly spinning missiles, simple formulas for resultant cross-wind force due to combination of control deflections are found. In the dynamical treatment, a simplified case is treated first in which the missile is weightless and transverse motion of the center of gravity is prevented (as, for example, when a spinning model is supported on gimbals in a wind tunnel). Control deflections are assumed to vary sinusoidally with roll angle, and the steady-state angles of attack and sideslip are calculated in terms of control-surface effectiveness parameters and conventional stability derivatives. In general there will be a phase difference between the direction of the resultant control-surface deflection and the resultant steady-state angular displacement of the vehicles. Since the effectiveness parameters include rate-of-deflection effects, both this phase angle and the angular displacement itself depend on the rate of roll. The more general case with gravity considered is then treated by similar methods.

W. R. Sears, USA

Vibration and Wave Motion in Fluids

(See also Revs. 625, 630, 857, 981, 1056, 1057, 1094, 1100, 1103, 1153, 1157, 1158)

911. Howells, I. D., The multiple scattering of waves by weak random irregularities in the medium, *Phil. Trans. Roy. Soc. Lond.* (*A*) **252,** 1015, 431–462, May 1960.

The known methods for treating "multiple scattering by supposing a wave to be scattered any number of times in accordance with the cross section for single scattering [are extended]. The equation of energy transfer for radiation in a uniform scattering atmosphere [is used] to describe the variation of average intensity in a randomly inhomogeneous medium." (From the author's abstract.)

In Part I, the known theory is reviewed, and an estimate is made of the conditions of its validity. The contents of Part II, entitled "Some solutions of the equations of transfer," are most easily described by listing the section titles. These are: (1) The equation of transfer for plane-parallel axially symmetric problems, in a statistically uniform and isotropic medium; (2) Solution dependent on time but not on space coordinates; (3) Steady-state problem; (4) Small total angular deviation of the radiation; (5) Approximate partial differential equation for small scattering angle, but large total angular deviation; (6) Solutions of the approximating partial differential equation, (a) semi-infinite scattering region, (b) slab of scattering medium, (c) angular distribution of emergent radiation; (7) Problem of oblique incidence; (8) Further comments on the general steady-state problem.

It can be seen from this list that a good many of the most interesting problems in the field are considered. However, the paper is not written for the tyro. Some familiarity at least with the earlier results in the field are important for an easy understanding of the paper.

M. Shinbrot, USA

912. Warren, F. W. G., Wave resistance to vertical motion in a stratified fluid, *J. Fluid Mech.* **7,** 2, 209–229, Feb. 1960.

Author presents a quite generalized analysis of the motion of bodies moving vertically in a stratified fluid. Commencing with the Euler equations of motion and introducing small perturbation density and pressure, the stream function for the axially symmetric, unsteady case is obtained. Utilizing Fourier and Hankel transforms, the solution for the stream function (for $t \to \infty$) is determined. The resulting expression is used to compute the streamlines and the distortion of constant density levels for a spindle-shaped body. Positions of the crests and troughs of the associated gravity waves are also determined. Wave resistance is computed for the sphere, cylinder and spindle shape; for each it is shown that a maximum wave resistance occurs as the velocity of the body is altered.

R. B. Banks, USA

913. Barakat, R. G., and Barakat, R. A., Optical studies of the diffraction of water waves by circular and thin elliptic cylinders, *J. Appl. Phys.* **31,** 3, 474–478, Mar. 1960.

Distorted image of grid reflected on free surface was photographed to measure height of water waves diffracted by rigid obstacles. Method is a variation of "ciel etoilé" (starry sky) method invented by a French engineer according to *Revue Générale de l'Hydraulique* [see number 43, Jan.–Feb. 1948, p. 12–22, where the principles of the method and a discussion of its application to model studies are given]. Authors describe their experimental procedure and compare their results on scattered intensity with theoretical calculations and with results of K. Mogi. Experimental values agree with theoretical ones for large distances from the obstacles. Authors verified the known fact that there are regions where the scattered and the plane waves cannot be separated. Reviewer wonders if the photograph of the experimental setup was purposely rotated 90° clockwise, thus forcing the reader to perform an opposite rotation of either head or magazine.

E. O. Macagno, USA

914. Abrezkov, V. I., Tetel'baum, I. M., and Cheliokov, N. I., Calculations for unsteady motion in the lower waters of a hydroelectric station, with the aid of electric modelling (in Russian), *Trudi Mosk. Energ. In-ta* no. 30, 35–50, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5081.

The Saint-Venant equations for unsteady motion in open channels, which, as is known, take the form of nonlinear equations of a hyperbola type, are not solvable in the general sense. The existing methods for the calculations of this motion are based on the application of different ways of numerical integration and the introduction into the equation of one or more assumptions to simplify the calculation. The authors of present paper make use of an assumption in relation to the dynamic equation which is usually applied in the method of momentary regimes; moreover, no account is taken of the squares of the magnitudes of the changes of the hydraulic characteristics of the flow specified by the wave character of the motion—being in conformity with the theory of waves of small amplitude; the above enables linearization of the dynamic equation to be carried out. The next step is the diversion of the part of the flow being investigated into a number of portions, followed by the performance of intelligent albeit simple conversions of equations recorded in finite differences applicable to the motion within the limits of these portions. As the result the authors obtain a system of differential equations equal in number to the number of portions in the lower water; the functions of time sought in these equations are the levels of the lines by means of which the lower water is divided into portions. The basic principles employed for the electromodelling of the obtained system of differential equations are explained. The possibility is also indicated of the solution of this system by integration on electronic dc integrators, which are issued serially by our industry. The authors of the paper carried out calculations with an electrointegrator type MN-2 for the unsteady motion in the lower water of the Kamsk hydroelectric station, the results of which show satisfactory convergence with the data of full-scale observations.

V. A. Arkhangel'skii

Courtesy Referativnyi Zhurnal, USSR

915. Bentwich, M., Use of a velocity-potential function in solving the wave equation for viscous media, *J. Acoust. Soc. Amer.* **32,** 8, 1080–1081 (Letters to the Editor), Aug. 1960.

916. Krasovskii, Yu. P., The theory of steady-state waves of large amplitude, *Soviet Phys.-Doklady* **5,** 1, 62–65, July/Aug. 1960. (Translation of *Doklady Akad. Nauk SSSR* (*N.S.*) **130,** 6, 1237–1240, Jan./Feb. 1960 by Amer. Inst. Phys., Inc., New York, N.Y.)

917. Reid, W. H., The oscillations of a viscous liquid drop, *Quart. Appl. Math.* **18,** 1, 86–89 (Notes), Apr. 1960.

For small oscillations at very small Reynolds number, it is shown that when the restoring force is due to surface tension the behavior is the same as that given by Lamb [*Proc. Lond. Math. Soc.* (*1*), **13,** p. 51, 1881] and Chandrasekhar [*Proc. Lond. Math. Soc.* (*3*), **9,** p. 141, 1959].

S. Corrsin, USA

918. Keck, W., and Beyer, R. T., Frequency spectrum of finite amplitude ultrasonic waves in liquids, *Physics of Fluids* **3,** 3, 346–352, May/June 1960.

Interest has grown in recent years in the propagation of vibrations too large in amplitude to be treated as if infinitesimal, but too small to be approximated by large amplitudes. For the infinitesimal case, a fluid medium may be regarded as linear, whereas

for large amplitudes dissipative terms may be ignored except at sharp (compression) wavefronts. Authors theoretically analyze the intermediate amplitude range by a perturbation technique, starting with the work of Fubini-Ghiron for the first approximation. The theoretical results are compared with the experimental results of Krassilnikov et al. E. Ackerman, USA

919. Wiegel, R. L., A presentation of cnoidal wave theory for practical application, *J. Fluid Mech.* **7,** 2, 273–286, Feb. 1960.

Author examines the leading results of existing theories of cnoidal waves, which appear to be appropriate to periodic waves progressing in shallow water. Selecting those results which appear to be most useful, author modifies them to derive data which can be used extensively by engineers. In particular expressions and graphs for the cnoidal wave shape, celerity, water particle velocity and local accelerations are given. Also, some results are compared with laboratory measurements.

G. Noseda, Italy

920. Nazarov, N. T., An analysis of the conditions prevailing during a water hammer effect in a pipe-conduit when the linear principle is in operation for changes in the opening of the slide gate (in Russian), *Trudi Kuibyshevsk. Inzh.-Stroit. In-ta* no. 5, 211–221, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5062.

An investigation is carried out on the reflection of waves of a water hammer due to the gate valve at the end of the pipe-conduit through which the liquid passes into the open air, and on the process of change in dynamic pressure at the gate valve when its opening is governed linearly by time. The information given in the paper is not new [see: L. Allievi, "Teoria del colpo d'ariete," Associazione Elettrotechnica Italiana, Collegio Ingegneri, Milano, 1913; M. A. Mostkov, Water hammer in hydroelectric stations," Moscow-Leningrad, 1938; N. A. Kartvelishvili, "Transient regimes in the power units of hydroelectric stations," Moscow-Leningrad, Gosenergoizdet, 1951]. N. A. Kartvelishvili

Courtesy Referativnyi Zhurnal, USSR

921. Amiradzhibi, R. K., The influence of the distribution of velocities over the section of the pipe-conduit on the magnitude of the water hammer (in Russian), *Soobshch. Akad. Nauk GruzSSR* **20,** 4, 399–404, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5063.

This is an axisymmetrical problem on the water hammer, with consideration for the unevenness of distribution of velocities over the tube's section, which is investigated as a single-dimensional problem. This is only possible because of the assumption made by the author of the constancy (both on the abscissa and by time) of the coefficient of unevenness α'

$$\alpha' = \frac{1}{v2\omega}\int_{\omega} u^2 d\omega$$

which is taken to be equal to the value it possesses in a steady regime. In the numerical example $\alpha' - 1 = 0.1$, a value which is higher than that customarily adopted for a steady regime ($\alpha' \leqslant 0.04$). N. A. Kartvelishvili

Courtesy Referativnyi Zhurnal, USSR

922. Zoryan, Z. A., Physical modelling of water hammer (in Russian), *Naucbn. Dokladi Vyssb. Sbkoly. Energetika* no. 1, 231–234, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5064.

An investigation is carried out with a model pipe-conduit with a rubber tire tube inflated with air placed in it to regulate the velocity of the impact waves. A formula is given for the velocity of propagation of the impact waves in such a pipe-conduit, the formula having been derived on the assumption that the air in the tire only contracts and expands in a transverse direction. This formula is akin to the Remeniéras formulas [G. Remeniéras, "Dispositif simple pour reduire la célerité des ondes élastiques dans les conduites en charge," *Houille Blanche* 1952]. The author states that his own formula gives good convergence with the experimental results. The investigation of water-hammer phenomena by the system investigated by the author contains no reference to the given assumption which appeared in the works of I. V. Egiazarov, A. A. Pervozvanskii and the abstractor [*Izv. Akad. Nauk. SSSR Otd. Tekh. Nauk* no. 11, 160–166, 1957].

N. A. Kartvelishvili

Courtesy Referativnyi Zhurnal, USSR

923. Haindl, K., Theory of the hydraulic jump in closed conduits and its use in practice (in Czech), Výzkumný Ústav Vodohospodářský, Práce a Studie, Praha no. 98, 72 pp., 1958.

Hydraulic jump in pipelines results in a flow under pressure and in change of the air content. Experiments by the author continued work done by American scientists after 1940 and entirely confirmed their results. New techniques (gamma-rays for air entrainment observation) were applied. Practical problems in design of chutes and culverts are discussed. S. Kolupaila, USA

924. Ovsepyan, V. M., Construction of powerful hydraulic rams (in Russian), *Izv. Akad. Nauk ArmSSR Ser. Tekbn. Nauk* **11,** 1, 3–14, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5131.

Questions are gone into concerning the utilization of large feed pressures and increases in the capacity of rams. It is shown that high-feed pressures do not induce dangerous pressures in the feed pipe of the ram or cavitation during the return wave. These phenomena are determined by the magnitude of the force pressure which has to be twice as large as the feed pressure in order to ensure the stable working of the ram. Increase in the capacity of the ram by means of increasing its diameter does not result in an increase in the impact stresses on the seating of the valve. When setting up batteries of rams a feed pipe common to them all can be used; this results in synchronous working of rams of different dimensions at any rate of the valve motion. It is a rational development to construct multi-valved rams with several impact valves and a single force valve and a single air valve.

A. I. Loshkarev

Courtesy Referativnyi Zhurnal, USSR

925. Okabe, J.-I., An impulsive motion of a liquid contained in a circular pipe, *Rep. Res. Inst. Appl. Mech. Kyusba Univ.* **7,** 26, 75–130, 1959.

The flow of a liquid contained in a long, circular pipe owing to an impulsive pressure which takes place suddenly on a section and spreads along the axis afterwards is calculated by the operational method.

In Appendix I the tables of $J_0(j_{0,n}\cdot\sigma)$ are shown, J_0 being the Bessel function of the first kind, $j_{0,n}$ its nth zero, and σ a number between zero and one; n is varied from one to forty at intervals of one, and σ, from zero to one at intervals of one-fortieth.

In Appendix II the problem of the propagation of the flow pattern in a long, rigid, circular pipe filled with a still fluid is studied, and it is shown mathematically that propagation with a finite velocity is impossible.

In Appendix III an approximate computation is suggested for the flow caused by an impulsive pressure traveling in a circular pipe.

From author's summary by G. H. Lean, England

926. Papadopoulos, V. M., A line source on an interface between a fluid and an elastic solid, Brown Univ., Div. Appl. Math. TR 56 (Contract Nonr 562 (10) (NR-064-406)), 39 pp., Apr. 1960.

In this paper the problem of interaction between infinitesimal disturbances propagated in a fluid and in an elastic solid across an infinite plane interface is examined by the method of dynamic similarity. The disturbance is the result of the setting up, at time $t = 0$, of an infinite line source of constant strength on the inter-

face; by the word source we imply within the fluid a line singularity associated with a flux which is uniform in all directions and with zero circulation. Seen from the solid the singularity is a line of pressure which is not, however, uniform in all directions.

There are three propagation velocities involved, the velocity of sound in the fluid and the velocities of shear and dilation waves in the solid. The form of the disturbances depends on the relative magnitudes of those velocities, as well as on the relative densities of the two media. Within the limitations of the theory of propagation of weak shocks, the method of dynamic similarity, which is closely related to the conical flow method of Busemann, leads to exact formulas for the stress and velocity components everywhere; these results satisfy the correct continuity conditions at the interface.

The nonuniform way in which the solution approaches the corresponding elastic half-space solution when the density of the fluid is small relative to that of the solid is described, and the nonuniform way in which the surface wave velocity is effected by the relative density is also discussed. Specific results which are found are that a pair of lines of stagnation move away from the source in opposite directions on the interface with the exact velocity of the Rayleigh wave for the solid. There is another pair of stagnation lines moving with velocity $2^{1/2}\ C_2$, where C_2 is the velocity of the shear waves, but only in cases when this velocity is smaller than the sound velocity in the fluid.

From author's summary by K. A. Faymon, USA

927. Breslin, J. P., A theory for the vibratory effects produced by a propeller on a large plate, *J. Ship Res.* **3,** 3, 1–10, Dec. 1959.

The flow generated on an infinite plane or wall by a single-bladed ship propeller rotating on a shaft parallel to the plane in a uniform superposed stream is first considered. After demonstrating that the pressure on the wall depends only on blade position and not upon the time-rate-of-change of blade position, the force and the moment on the plane about a transverse axis are computed and found to be given by very simple formulas. Under the assumed neglect of the interferences arising from the image of the propeller in the wall, it is shown that the net force and moment on the wall are zero for all lightly loaded propellers having two or more blades. The case of nonuniform inflow is considered and shown to give nonzero vibratory forces. The case of uniform inflow is still of interest because the zero force and moment result does not mean that an elastic wall would not vibrate, and to substantiate this, a formula for the deflections of a thin "infinite" plate is given. This formula has not been evaluated because of its complexity. It is recommended that numerical evaluation be undertaken through the use of a high-speed computer.

From author's summary by B. W. Wilson, USA

928. Sando, R. M., Two nomograms that simplify calculations of compressibility of fluids, pressure change vs. volume change and velocity of a pressure wave, *Mach. Design* **32,** 20, 137–140, Sept. 1960.

Fluid Machinery

(See also Revs. 838, 852, 901, 914, 927, 1015)

929. Oba, R., Theory of flow through profiles with large camber and thickness arranged in cascade with small pitch chord ratio (in English), *Ing.-Arch.* **27,** 4, 276–284, 1959.

Author extends Howell's method [Howell, A. R., *Phil. Mag.* **39,** p. 913, 1948; AMR **3**(1950); Rev. 732] of calculation of potential flow through cascades. Howell's transformation sequence was cascade– S-shaped single profile – near circle – circle. Oba's transformation sequence is cascade– S-shaped single profile – back to shallow S-shaped cascade – near circle – circle. New method provides solutions to flow through cascades of high camber (e.g. turbine cascades). Calculated pressure distributions agree well with experimental data.

Howell's paper gave simple outlet angle-inlet angle expression for low-camber cascades. New paper gives no similar final result, but is a very useful addition to literature on cascade transformation.

J. H. Horlock, England

930. Gomi, M., On the deviation of outlet flow angles caused by secondary flows in turbine cascades (1st Report), *Bull. JSME* **2,** 8, 608–615, Nov. 1959.

A formula is derived to calculate deviation of outlet angles from a cascade caused by secondary flow. Incompressible and inviscid flow is assumed in the main stream. It is also assumed that vortexes remain a straight line traveling through the cascade. Smith's equation is applied [Smith, WADC TR 55–348, (1955–8)]. The results of the approximate theoretical equations are compared with cascade tests. A better correlation is obtained if the flow passage beyond the cascade is assumed to be deformed. Poor correlation is obtained for thick boundary layers, since the assumption of semi-infinite span and vortex concentration in the centroid is incorrect.

G. Miskolczy, USA

931. Kamimoto, G., Ando, H., and Akamatsu, T., On the flow in a water turbine of axial flow type, *Bull. JSME* **2,** 8, 616–623, Nov. 1959.

A model Kaplan turbine was tested in air. The flow upstream and downstream from the runner was measured. The pressure distribution along the blades was also observed. The pressure distribution is measured along an isolated airfoil and an airfoil in a two-dimensional cascade. The results for an isolated airfoil differ considerably from those obtained on the runner. The cascade tests however show good agreement. A three-dimensional theory is developed by conformally mapping a circular wing lattice of logarithmic spirals. The results of the three-dimensional theory agree with the experimental values.

G. Miskolczy, USA

932. Gutovskii, E. V., Investigation of an exciting hydrodynamic force, acting on the blades of axial hydroturbines (in Russian), *Trudi Leningrad Politekhn. In-ta* no. 193, 24–37, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5118.

There is a history of cases of blade fracture in axial hydroturbines which appears to be of a vibrational character. The source of the vibrations can be attributed to the axial asymmetry of the flow in front of the working wheel and, as a secondary cause, the uneven inflow and outflow of water in the spiral chamber and the suction tube, and also as a consequence of the presence of the blades of the control apparatus and the fins of the stator. Analysis of the character of the flow in the clearance between the control apparatus and the working wheel, where the flow makes an angle of 90°, disclosed that the basic source of the exciting force acting on the blades of axial hydroturbines is the lower part of the blades of the control apparatus which gives rise to a flow having a measure of heterogeneity, sufficient to impart considerable vibration to the peripheral portion of the blade. In this portion of the part of the turbine between the inlet and outlet valves the edge traces fail to disperse because of the small clearance between the outlet edge of the blade in the control apparatus and the inlet edge of the blade of the working wheel. Experimental investigation confirmed these results of the theoretical analysis. The amount of heterogeneity in the flow beyond the control apparatus was found to be particularly large at small loads, the reason being that when the control apparatus is working with small openings a diffusion current is created at the outlet. This explains the generally observed increase in vibration of the blades at small loads and the transmission of the vibration to the whole unit.

V. Kh. Abiants

Courtesy Referativnyi Zhurnal, USSR

933. Kvyatkovskii, V. S., Calculations for the blades in working wheels of radially-axial hydroturbines (in Russian), *Trudi Vses. Nauk-i. In-ta Gidromashinostr.* no. 21, 39–56, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5121.

From a study of the physical picture presented by the flow beyond the wheel of a hydroturbine, created by the lattice profile, the following was established: (1) that outlet angle of the flow acquires its maximum value at the points of convergence of the flow with the blade; (2) points with maximum and minimum velocities are dispersed between the blades, on both sides of which the velocities are equal at the outlet to the channel. The fall of pressure between the points of given velocities is assumed to be proportional to the mean fall on the blade. As shown by the analysis of the differential equations describing the potential current in the calibration zone, which is given in the paper, the angle of the incomplete twist of the flow is approximately proportional to the load on the blade. The author obtains a correlation for the evaluation of the safety reserve for cavitation by scrutiny of the conditions which are dangerous from the viewpoint of cavitation in the main flow, at its outlet from the wheel (not on the blade).

M. V. Polikovskii

Courtesy Referativnyi Zhurnal, USSR

934. Kolpakov, L. G., An approximate solution for the determination of the mean hydrodynamic angle of outlet of the flow from the lattices of turbines in series of turbo-drilling machines (in Russian), *Sb. Tr. Ufimsk. Neft. In-ta* no. 2, 137–141, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5119.

Formulas are considered for the determination of the angle of retardation of the flow at the outlet of an axial turbine lattice of a turbo-driller. The author proposes the use of the formula

$$\operatorname{ctg} \beta_{2m}' = \frac{\operatorname{ctg} \beta_2}{\sqrt{1 + \frac{1}{2}\tau(t/b_0)\sin \beta_2}}$$

which gives, he asserts, a better convergence with the experimental. This formula is derived by a comparison of Euler's equation for an infinite number of blades with the equation corrected for a finite number of blades. It is a substitute for the formula proposed by P. P. Shumilov ["Theoretical basis of turbine drillers," Gostoptekhizdat, 1943]

$$\sin \beta_{2m}' = \frac{\sin \beta_2}{1 + \frac{1}{2}\tau(t/b_0)\sin \beta_2}$$

(where β_{2m}' is the mean angle between the direction of the flow at the outlet and the axis of the lattice, β_2 the angle between the tangential to the profile at the outlet and the axis of the lattice, t the pitch of the lattice, b_0 the height of the lattice, τ a correction coefficient), which gives too high a magnitude for the retardation angle. The author's views on the necessity to replace in Shumilov's formula the sines by cotangents and, correspondingly, the competence of the proposed formula arouse some doubts, because of divergencies in the two formulas in regard to determinations: by the author and in Pflederer's coefficient

$$1 + \frac{r}{2}\,\frac{t}{b_0}\sin \beta_2$$

the angles β are taken in relation to the direction of the lattice's flow while Shumilov does so in relation to the axis. The paper contains some errors. In particular the numerical value of coefficient τ given by the author does not agree with the value recommended in the study quoted by him.

N. A. Kolokol'tsov

Courtesy Referativnyi Zhurnal, USSR

935. Chechel', N. S., The influence of the number of blades in the working wheel on the power indicators of variable-pitch hydroturbines of very high speeds (in Russian), *Trudi Leningrad Politekhn. In-ta* no. 193, 38–50, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5120.

This paper deals with an attempt to establish ways and means to reduce losses in the part of a turbine between the inlet and outlet valves. The basis of the attempt is the experimental investigation of the characteristics of two types of models of high-speed variable-pitch bladed hydroturbines with different numbers of blades on the working wheel and with geometrically similar lattices. The relation is established, for the models being investigated, between profile and nonprofile (losses on account of secondary flows) losses in the working wheel and losses in the suction tube. One of the ways for reducing the loss appears to be the selection of the optimum number of blades of the given geometrical form.

N. A. Kolokol'tsov

Courtesy Referativnyi Zhurnal, USSR

Flow and Flight Test Techniques and Measurements

(See also Revs. 626, 820, 838, 853, 856, 913, 931, 990, 1108, 1153)

936. Bakhtin, V. I., Dynamics of a self-balancing manometer for measuring low gas pressures, *Measurement Techniques* no. 7, 511–515, June 1960. (Translation of *Izmeritel'naya Tekhnika* no. 7, 16–17, July 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

An extremely brief description is given of an electromagnetic, self-balancing, twin-capsule manometer which covers the absolute pressure range 10^{-3} mm Hg to 27 mm Hg. The stated error in measurement is not clearly defined and implies a constant error of ± 3% over the whole range. The inactive capsule is sealed and contains a getter which obviates the need for continuous pumping. Author develops a third-order differential equation for this type of manometer together with its electronic servo. It is assumed that pressure input varies linearly with time and a general solution is obtained for the equation. The stability of the system is discussed with regard to the physical parameters involved. A numerical value is obtained for a coefficient which determines the constant error of self-balancing if a pressure range of 10^{-3} mm Hg to 100 mm is to be covered. The translation contains nine errors (or misprints) in the mathematics and because of this the reviewer has found it necessary to refer to the original, which contains four of these errors (or misprints). The conclusions are not affected by the errors.

J. Busing, England

937. Shkarbul', S. N., The measurement of pressures on the rotating components of turbomachine models (in Russian), *Nauchno-Tekhn. Inform. Byul. Leningrad Politekhn. In-ta* no. 3, 9–15, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6604.

Paper describes the principle of operation of a multi-point manometer (with 12 to 15 points) adopted by the author for measuring pressures on the rotating wheel of a centrifugal compressor at peripheral velocities on the circumference of the working wheel of the order of 80 to 100 m/sec. Viewed schematically, the apparatus has the appearance of a cylinder on the outer surface of which U-shaped glass manometer tubes containing liquid have been fixed. The pressure to be measured is connected to these tubes. The axis of the apparatus and the axis of the shaft of the compressor are vertical. The apparatus and the rotor are interconnected and rotate at an identical angular velocity ω. The readings of the pressures on the revolving manometer are accomplished by means of a stroboscope. Some questions of method connected with the measurement of pressures by the proposed apparatus are gone into; in particular, an investigation was made to ascertain the influence of centrifugal forces and forces of surface tension on the form of

the free surface of the liquid in the manometer tube. It was indicated that work on the improvement of this rotating battery-type manometer is to be continued. B. S. Dorogov

Courtesy Referativnyi Zhurnal, USSR

938. Zaichikov, P. F., and Kryazheva, V. A., Some results of the investigation of the work of a bladed anemometer with changes in the density of the air (in Russian), *Trudi Tsentr. Aerol. Observ.* no. 22, 60–64, 1957; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6579.

Results are furnished of the experimental investigations regarding the influence of the density of air on the precision of the readings of a bladed anemometer; the experiments were carried out on apparatus capable of rotation, enclosed in a baro-chamber. It was shown that the correction necessary for the anemometer readings because of the air's density increases with altitude and is specially sensitive after 8 km. An experimental graph is put forward to show the relation of the anemometer's readings to the number of revolutions and density of the incoming flow. The analytical relations approximating these curves differ from the existing ones. V. M. Borisenko

Courtesy Referativnyi Zhurnal, USSR

939. Vasilevskii, Yu. M., An ultrasonic measuring instrument for flow velocity (in Russian), *Priborostroenie* no. 12, 15–16, 1957; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 2845.

The comparison of the frequencies of repetition of rectangular impulses in an ultrasonic velocity measuring instrument enables the velocity of propagation of the sound in the medium to be eliminated from the final expression and at the same time to correct the instability in the readings of the instrument which is linked with the relation of the velocity of propagation to the physical parameters of the medium. It is possible to calibrate the apparatus in units of consumption once the relation is established between the consumption of the liquid medium and the magnitude of the mean velocity of the flow, measured by the apparatus. An outline design of the ultrasonic consumption meter is given.

Yu. G. Zakharov

Courtesy Referativnyi Zhurnal, USSR

940. Tol'stman, V. F., Measurement of the flow of liquids by means of angled flow meters (in Russian), *Vodosnabzh. i San. Tekhn.* no. 4, 15–16, 1958; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 2851.

When fitting flow-meters in a vertical plane the filling of the impulse tubes with a medium of a different density to that of the medium being measured results in an error in the determination of the flow when using the formula for the customary quadratic relation between the flow and the drop in level, due to the variable levels assigned to the points of discharge. The author, after indicating the unsuitability for this case of manometer flow meters which automatically derive the quadratic root from the drop in level, shows the necessity of adopting special manometer flow meters the zero reading of which would correspond to the fall in level between the points of selection.

A. A. Rabinerson

Courtesy Referativnyi Zhurnal, USSR

941. Martin, J. J., and Pabbi, V. R., Use of momentum balance in calibrating orifices for flow of gases, *AIChE J.* **6,** 2, 318–321, June 1960.

A method of determining the absolute calibration of a gas-flow orifice without the use of gas holders or any comparative device is described. The method is based on the application of the momentum balance, as well as the energy balance, to the flow of the gas. The application requires the measurement of pressures on the face of the orifice in addition to the usual pressure-drop measurements along the axis of flow.

Orifice coefficients determined by the force-momentum principle are shown to agree within an average deviation of 1.4% with those determined by other standard techniques. Also the application of the force-momentum principle demonstrates clearly why orifice coefficients are much less than unity.

From authors' summary

942. Kraftmakher, Ya. A., A viscometer with induction transmitters (in Russian), *Izmer. Tekhnika* no. 5, 78–79, 1957; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 2859.

A falling-ball method is described for measuring viscosity, supplemented by a simple electronic device with induction transmitters. This method enables measurements to be made with opaque liquids, at high pressures and so forth, when direct visual observation of the ball would be difficult or impossible.

V. I. Troshin

Courtesy Referativnyi Zhurnal, USSR

943. McDearmon, R. W., Investigation of the flow in a rectangular cavity in a flat plate at a Mach number of 3.55, NASA TN D-523, 42 pp., Sept. 1960.

An investigation has been made in the Mach 3.5 blow-down jet of the Langley high-temperature fluid mechanics section of the effects of systematic variations of depth, span, and upstream and downstream lip radii on the flow phenomena in a rectangular cavity in a flat plate. Pressure distributions in the cavity were measured and schlieren photographs of the shock structure immediately above the cavity were taken. The critical depth (depth beyond which depth increases had no effect on the pressure distribution in the cavity) and the pressure distribution in the very shallow cavity were predicted analytically. The boundary layer of the flow approaching the cavity was turbulent.

From author's summary

944. Christopher, K. W., and Johnson, V. E., Jr. Experimental investigation of two low-drag supercavitating hydrofoils at speeds up to 200 feet per second, NASA TN D-436, 32 pp., Aug. 1960.

Two supercavitating hydrofoils—one of aspect ratio 1 and the other of aspect ratio 3—designed for low-drag characteristics have been tested at or near zero cavitation numbers. The tests were made over a range of depths of submersion from 0 to approximately 1 chord and of angles of attack from 4° to 20°. Experimental values of lift coefficient and center of pressure were in good agreement with theory. Experimental values of drag are less than 10% higher than those predicted by theory. The theoretical values for minimum angle of attack for operation with the upper surface of the hydrofoil unwetted define the lower limits of angle of attack for which the experimental values of lift coefficient are either in agreement with or slightly greater than those predicted by theory. From authors' summary

945. Smith, C. C., Jr., Wind-tunnel investigation of a small-scale model of an aerial vehicle supported by tilting ducted fans, NASA TN D-409, 17 pp., Aug. 1960.

The model had three ducted fans arranged in a triangular fashion (one fan at the front and two at the rear) that could be tilted relative to the airframe for forward flight. The paper presents the results of tests to determine the static longitudinal and lateral stability characteristics of the model and includes a comparison with a tandem fixed-duct configuration. The results of the tests indicate that the tilting-duct arrangement has less nose-up pitching moment and less static longitudinal instability for a given forward speed than the tandem fixed-duct arrangement.

From author's summary

946. Turner, T. R., A wind-tunnel investigation of the development of lift on wings in accelerated longitudinal motion, NASA TN D-422, 16 pp., Aug. 1960.

Results are presented of a wind-tunnel investigation to determine the effect of acceleration on the development of lift in a

simulated catapult take-off for a two-dimensional wing, an unswept wing, a swept wing, and a delta planform wing. Each of the wings investigated developed 90% of its steady-state lift within 7 chord lengths of travel. The experimental results agreed qualitatively with results calculated from theory.

From author's summary

947. Bowman, J. S., Jr., and Healy, F. M., Free-spinning-tunnel investigation of a 1/20-scale model of an unswept-wing jet-propelled trainer airplane, NASA TN D-381, 18 pp., June 1960.

Results of an investigation of a dynamic model in the Langley 20-foot free-spinning tunnel are presented. Erect and inverted spin characteristics were determined for a range of mass distribution conditions. Recovery from spins obtained was attempted by various control manipulations. From authors' summary

948. Kutterer, R. E., The present state of free flight installations (in German), Jahrbuch Wissenschaft. Gesellsch. Luftfahrt, 1957, 261-278.

An excellent survey is given on the experimental techniques employed in the study of free-flying models in a gun-tunnel. This survey includes a description of most of the installations known for this duty, starting with the pre-war test stand at Braunschweig and including the installations now in use in USA (APG, Maryland; NOTS, Inyokern; NOL, White Oak), Canada (CARDE, Quebec), England (NPL, Teddington) and France (LRBA, Vernon; LRSL, St. Louis). J. K. Yap, Holland

949. Quigley, H. C., Anderson, S. B., and Innis, R. C., Flight investigation of the low-aspect characteristics of a 45° swept-wing fighter-type airplane with blowing boundary-layer control applied to the leading- and trailing-edge flaps, NASA TN D-321, 44 pp., Sept. 1960.

The study included documentation of the low-speed handling qualities as well as the pilots' evaluation of the landing-approach characteristics. The results are compared with those in NACA RM A58E05 for the airplane with a slatted leading edge and the same trailing-edge flap. Several of the factors limiting the use of the high lift possible with leading-edge boundary-layer control flaps were associated with the high angles of attack required for low-speed flight in the test airplane.

From authors' summary

950. Hurt, G. J., Jr., and Whitten, J. B., Flight investigation of an automatic pitchup control, NASA TN D-114, 27 pp., Aug. 1960.

The pitching-moment characteristics of a transonic fighter airplane which was subject to pitchup were altered by driving the stabilizer in accordance with a signal that was a function of the measured angle of attack and the pitching velocity. The automatic system was capable of extending the region of positive stability for the test airplane to angles of attack above the basic-airplane pitchup threshold angle of attack. In most cases a limit-cycle oscillation about the airplane pitch axis occurred.

From authors' summary

951. Jackson, H. H., Free-flight measurements of the zero-lift drag of several wings at Mach numbers from 1.4 to 3.8, NASA TN D-395, 27 pp., June 1960.

An investigation was made to determine the zero-lift drag at high Reynolds numbers and at high supersonic Mach numbers, 1.4 to 3.8, of some swept, unswept, delta, and diamond wings of current interest. The wings were all of the same exposed area with thickness ratios varying from 5 to 3% and were mounted on bodies of fineness ratio 10.75. Of the wings tested, the 60° delta wing and 40.87° diamond wing had the lowest drag, the drag coefficients of the two wings being the same and showing very little change with Mach number from 2.4 to 3.8.

From author's summary

952. Stephenson, J. D., A technique for determining relaxation times by free-flight tests of low-fineness-ratio cones; with experimental results for air at equilibrium temperatures up to 3440°K, NASA TN D-327, 55 pp., Sept. 1960.

Relaxation times were determined by measuring the shapes of the bow shock waves on low-fineness-ratio cones in free flight and comparing these wave shapes with those calculated by a theory that is applicable to nonequilibrium flow. At temperatures where the excitation of molecular vibration was the principal nonequilibrium effect, measured relaxation times in air were in agreement with values estimated from shock-tube measurements in pure oxygen and nitrogen. From author's summary

953. Holister, G. S., Brackmann, R. T., and Fite, W. L., The use of modulated atomic-beam techniques for the study of space-flight problems, AFOSR TN 59-1033 (General Atomic, Div. of General Dynamics Corp. GA-1024), 17 pp., Oct. 1959.

For investigating atom-surface interactions in atmospheres simulating the free molecular flow regime the use of hydrogen and oxygen beams are of interest. The difficulty associated with tracing an atomic beam through a residual gas of extremely low density is accomplished in this case by modulating the atomic beam. This is done mechanically by interrupting it at a frequency of 100 cps. Under these conditions, effects arising from the beam may be identified by its occurrence at the modulated frequency in a specific phase. Hence it is possible to use mass-spectrometric detection of the beam, since electron-impact ionization cross sections for hydrogen and oxygen atoms are known.

Two experiments are discussed: (1) Incident beam impinging on surface and particles leaving are examined by mass-spectrometer. In this manner thermal accommodation coefficients are determined for various surfaces and gases. (2) Beam impinges surface placed on a torsion balance, and momentum transfer measured directly. Results of a number of experiments using this technique are presented. S. Lampert, USA

Thermodynamics

(See also Revs. 595, 880, 953, 979, 1000, 1014, 1027, 1034)

954. Weir, C. D., Optimization of heater enthalpy rises in feed-heating trains, Instn. Mech. Engrs., Prepr., 17 pp., 1959.

Author discusses the exact relationships obtained for the optimum distribution of heater enthalpy rises in a contact heater train for the simple regenerative subcritical cycle, the single reheat cycle with one and several heaters at and above the reheat point, and also for the double reheat cycle. The problem of supercritical cycles and the method of taking exact account of the influence of the feed pumps are also discussed.

From author's summary by A. E. Seigel, USA

955. Gates, D. S., and Thodos, G., The critical constants of the elements, *AIChE J.* **6,** 1, 50-54, Mar. 1960.

The authors have developed critical constants for the metallic elements by use of van der Waal's equation of state and critical temperatures and pressures derived from correlation of existing data. Using critical constants for the permanent gases except helium, which did not follow the relationship, plus bromine, phosphorus, iodine and sulphur the authors derived an equation expressing the critical temperature in terms of the normal boiling temperature.

Utilizing sodium as a basis for the low-temperature-boiling metallic elements, and copper for the high-temperature element in conjunction with vapor pressure data, Cox-Othmer-type charts of vapor pressure were made. From the critical temperature correlation the critical pressure could be obtained from the chart. Having the

critical temperature and pressure, both van der Waal's constants a and b were obtained, as was the critical volume.

Based upon existing data, the authors' treatment has been very thorough and provides a source for determining high-temperature properties of metallic elements, and serves a need until experimental values are obtained. However, reviewer considers a high degree of uncertainty must be placed in the reported values due to the extreme range of extrapolation, and the possibility of different vapor species present under conditions of high temperatures and high pressures. C. A. Alexander, USA

956. Sankar, R., The van der Waal's interaction of particles, *J. Indian Inst. Sci.* **42,** 1/2, 17-22, Jan./Apr. 1960.

Recently Mrs. Vold [*Proc. Ind. Acad. Sci.* **46,** (A), 2, 152-166, Aug. 1957] has evaluated an expression for the interaction energy of two ellipsoidal particles situated in any manner relative to each other. She has assumed the law of interaction as the inverse sixth power of the distance and has obtained the expression for the energy in terms of a series in ascending powers of $(1/R)$. She has given explicitly the coefficients necessary to calculate the energy up to the first three terms of the series. In the present note the same problem has been reconsidered for the case in which each particle has three principal planes of symmetry. A series expression has been obtained as in Mrs. Vold's paper on the assumption that the law of interaction is the $(2k)$th power of $(1/R)$, where k may be fractional. The result is expressed in terms of various order moments of the particles. These moments have been tabulated for the case of ellipsoids and elliptic cylinders. No applications have been attempted as the applications given in the paper under reference can easily be repeated for this also.

From author's summary

957. Lebowitz, J. L., Asymptotic value of the pair distribution near a wall, *Physics of Fluids* **3,** 1, 64-68, Jan./Feb. 1960.

Using the virial theorem for momentum fluctuations in a system in equilibrium, and assuming the absence of long-range correlations in a fluid, an expression is derived for the probability that a molecule is at a given distance from another one at the wall. The result is applied to derive an expression for the second virial coefficient and for the equation of state for a one-dimensional hard sphere gas. D. Ter Haar, England

958. Mason, E. A., and von Ubisch, H., Thermal conductivities of rare gas mixtures, *Physics of Fluids* **3,** 3, 355-361, May/June 1960.

Recent measurements of the thermal conductivities of all ten possible binary mixtures of the rare gases and of the ternary mixture He-Kr-Xe at 29° and 520°C are compared with theoretical calculations. Three calculations are carried out, based on: (1) rigorous kinetic theory, (2) an approximate formula which uses only conductivities of the pure components, and (3) a new semiempirical formula which also requires knowledge of the conductivity of one composition of binary mixture. The agreement is generally satisfactory and furnishes support for the usefulness and accuracy of the formulas used.

From authors' summary by L. Talbot, USA

959. Eckert, E. R. G., Ibele, W. E., and Irvine, T. F., Jr., Prandtl number, thermal conductivity, and viscosity of air-helium mixtures, NASA TN D-533, 39 pp., Sept. 1960.

Prandtl number measurements of air-helium mixtures were performed at a temperature of 270°K for mixtures ranging from pure air to pure helium. Various methods of predicting the thermal conductivity and viscosity of binary mixtures were also investigated and results obtained by use of these methods are compared with the experimental results. Dimensionless conductivities, viscosities, and Prandtl numbers were calculated over the temperature range of 200° to 1500° K for mixtures ranging from pure air to pure helium.

From authors' summary

960. Hirschfelder, J. O., Taylor, M. H., and Kihara, T., Viscosity of two component gaseous mixtures, Univ. Wisconsin, Theoretical Chem. Lab., WIS-OOR-29, Series 2 & 5, 16 pp., July 1960.

The conditions are found where the viscosity of a binary mixture of dilute gases either has a maximum or a minimum with respect to variations in the composition. A maximum in the viscosity is most likely to occur for a mixture of a polar and nonpolar gas in which the viscosities of the pure components are nearly equal and their molecular weights are quite different. A minimum should occur for a mixture of two nonpolar gases in which both the viscosities and molecular weights of the pure components are nearly equal. There are many experimental examples of maxima in the viscosity but up to the present time no cases have been discovered where the viscosity has a minimum. The maximum value of the viscosity and the mole fraction at which it occurs can be used to determine the energy of interaction between unlike molecules.

From authors' summary

961. Barua, A. K., Thermal conductivity and Eucken-type factor for the binary mixtures H-He, H-Ne, H-Kr and H-Xe, *Indian J. Phys.* **34,** 4, 169-183, April 1960.

In order to test the recent formulas for the thermal conductivity of polyatomic gas mixtures, the thermal conductivity of H_2-He, H_2-Ne, H_2-Kr and H_2-Xe mixtures have been measured at 30°C and 45°C by using the thick-wire-variant of the hot-wire method. The experimental values of the thermal conductivity of the pure gases and their binary mixtures is lower than those given by Hirschfelder's theory based on the local chemical equilibrium assumption. It has been suggested that this discrepancy between theory and experiments at the temperatures under consideration is due to the nonvalidity of the condition of local chemical equilibrium. Apart from this drawback Hirschfelder's theory has been found to represent the concentration dependence of the thermal conductivity of polyatomic gas mixtures quite satisfactorily. The more rigorously derived formula of Hirschfelder has been found to represent the thermal conductivity of gas mixtures better than the approximate equation of Mason and Saxena. From author's summary

962. Matschke, D. E., and Thodos, G., The PVT behavior of methane in the gaseous and liquid states, *J. Petroleum Technol.* **12,** 10, 67-71, Oct. 1960.

963. Horlock, J. H., Approximate equations for the properties of superheated steam, *Proc. Instn. Mech. Engrs.* **173,** 33, 779-794, 1959.

See AMR **13**(1960), Rev. 392.

964. Cardullo, M. W., Influence coefficients for real gases, *J. Aero/Space Sci.* **27,** 6, p. 546 (Readers' Forum), June 1960.

965. Petrick, M., and Swanson, B. S. Expansion and contraction of an air-water mixture in vertical flow, *AIChE J.* **5,** 4, 440-445, Dec. 1959.

An experimental two-phase flow study of an air-water system, at atmospheric pressure, to obtain information on the effect of expansion or constriction of the channel on the flow of the two phases. Small changes of the relative velocity and of the ratio of air cross section to water cross section were observed. A collimated beam of gamma rays was used to measure densities. The data is compared with a simple theory based on empirical assumptions. The reviewer believes that the effects of turbulence in the two phases should be investigated in greater detail.

R. Betchov, USA

966. Gross, R. A., and Eisen, C. L., On the speed of sound in air, *Physics of Fluids* **2,** 3, 276–279, May/June 1959.

Authors consider speed of sound behind air shocks with shock Mach numbers up to about 20, initial pressures of 10^{-6}, 10^{-3}, and 1 atm, and temperature 537° R. Speed varies owing to sensitivy of dissociation reactions to pressure. Distinction is made between equilibrium speed (zero frequency, infinite reaction rate) and frozen speed (infinite frequency, zero reaction rate). Machine program is used to obtain basic data, mole fractions of reactants and products as function of shock Mach number. Calculated ratios of equilibrium to frozen speeds in air as function of shock Mach number are less than unity, but show maxima (for all initial pressures) near Mach 12, near where concentration of reaction product NO has maximum.

V. Salmon, USA

967. Molmud, P., Expansion of a rarefied gas cloud into a vacuum, *Physics of Fluids* **3,** 3, 362–366, May/June 1960.

Author attacks the problem of the expansion into a vacuum of gas clouds having simple initial configurations. The molecules have a Maxwellian velocity distribution and at time $t = 0$, coinciding with the removal of the shell bounding the gas cloud, the molecules move radially from each point source with constant velocities. The purpose is to evaluate the density of molecules at a point $\vec{x}$ and at a time $t > 0$.

As the first problem author solves the free molecular expansion of an instantaneous point source. The resultant formulas refer to the density and temperature. Next, author attacks the problem of the expansion of clouds of simple initial configuration. Three configurations are chosen, which differ one from each other in the form of the density at the time $t > 0$. Keller's solution [J. B. Keller, *Comm. Pure Appl. Math.* **1,** p. 275, 1948; AMR **2**(1949), Rev. 1299] appears as a particular case of the present approach. The following regions, initially occupied by the gas cloud of a constant density, are considered: $|x| < a$, the interior of the cylinder; the interior of the sphere. The free molecular expansion takes place in a vacuum. As the next item author discusses details of the expansion of an initially uniform spherical gas cloud. As the last item author compares the free molecular flow solution with that obtained from the equations of gas dynamics. Since there is no analytical solution of the latter type, author quotes the results obtained on a large-scale digital computer by W. Strang. A graphical comparison shows that there is very little difference between the two solutions even at the largest times illustrated.

The paper is illustrated well by means of diagrams.

M. Z. v. Krzywoblocki, USA

968. Isbin, H. S., Rodriguez, H. A., Larson, H. C., and Pattie, B. D., Void fractions in two-phase flow, *AIChE J.* **5,** 4, 427–432, Dec. 1959.

The fraction of flow cross section occupied by the gas phase is measured for a mixture of steam and water, using a collimated beam of gamma rays. The authors' results, together with many previous results, are summarized and compared with various theoretical and empirical expressions.

Paper provides useful raw information and references on a difficult subject.

R. Betchov, USA

969. deBethune, A. J., Fuel cell thermodynamics, *J. Electrochemical Soc.* **107,** 11, 937–939, Nov. 1960.

A simple fuel cell, operated reversibly, puts out, either electrochemically or in osmotic-mechanical form, an amount of useful work equal to the chemical potential (free enthalpy, Gibbs free energy) $-\Delta G$ released isothermally by the fuel plus oxygen upon their combination. This may be larger than the corresponding Carnot output $(-\Delta H)(T_h - T_l)/T_h$ of the same amount of fuel used to fire a reversible heat engine.

A coupled (regenerative) fuel cell regenerates the cell reagents by decomposing the reaction products at a high temperature (obtainable from a nuclear reactor). It thus acts as a heat engine in converting heat from the nuclear reactor into useful work. Its reversible work output, given by the summation of $-\Delta G$ for all isothermal steps, is exactly equal to that predicted from the heat inputs by Carnot's theorem in integral or differential form, for any fuel cell reaction, and for zero and finite values of ΔC_v for the cell reaction. The useful work output of an idealized practical irreversible fuel cell cycle is also given.

From author's summary

Heat and Mass Transfer

(See also Revs. 593, 643, 645, 648, 654, 658, 781, 870, 871, 872, 880, 883, 884, 886, 887, 890, 954, 958, 961, 967, 1027, 1035, 1039, 1060, 1065, 1072, 1082, 1117, 1126)

970. Boley, B. A., Upper bounds and Saint-Venant's principle in transient heat conduction, *Quart. Appl. Math.* **18,** 2, 205–207, July 1960.

Some upper bounds for temperature are derived for the transient heat conduction in a body subsequent to the liberation of a unit heat source at a point on the boundary. Analysis is an extension of author's steady-state results [AMR **12**(1959), Rev. 5403].

E. H. Mansfield, England

971. Lewis, J. A., and Riney, T. D., Temperature rise in an infinite medium heated by a planar source, *J. Soc. Indust. Appl. Math.* **8,** 2, 249–271, June 1960.

The heat-conduction problem is investigated in an infinite homogeneous three-dimensional medium with uniform initial temperature, heated by a planar source of intensity $Q(t) \geq 0$ per unit time per unit area ($t > 0$). Integral form of the solution is written, useful for further investigations. With its help and with the help of Laplace transformation, author derives expressions for asymptotic behavior of the solution for large and small values of t. Solving for the maximum temperature rise at a given instant, author shows that, of all planar sources of fixed area, the circular one (the disk) produces the largest temperature rise. As to the location of the maximum, he shows that it occurs always in the plane of the heat source; it occurs even within the source if the area of the source is convex or if $Q(t)$ is a nondecreasing function of time. Steiner's symmetrization is used to show that the maximum lies along lines of symmetry, if any such lines exist. Then, a method of sectors is shown, very useful for numerical calculation. In the appendix, a note about a lower bound of the solution is presented.

The paper is very carefully and clearly written.

K. Rektorys, Czechoslovakia

972. Newcomb, T. P., Flow of heat in a composite solid, *Brit. J. Appl. Phys.* **10,** 5, 204–206, May 1959.

Author solves one-dimensional heat-conduction problem of composite slab insulated at outer faces; interface is subjected to a heat flux decreasing linearly with time. Model represents braking at constant deceleration, where heat is shared between brake band and drum. Solution is obtained by Laplace transform and confirmed by experimental data.

Reviewer believes Eqs. [5] and [6] misleading; only their sum can be and is, in fact, satisfied.

J. S. Thomsen, USA

973. Andriankin, E. I., Propagation of thermal waves from the boundary of two media, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **23,** 5, 1420–1423, 1959. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Author gives nondimensional form of equation for one-dimensional heat conduction and boundary conditions when medium suffers change of phase at intermediate temperature. Solutions for

several initial value problems are inferred from earlier work on flow in porous media. No account is taken of effects which would arise from convection, though these would often be dominant in practice. B. R. Morton, England

974. Campbell, W. F., Periodic temperature distribution in a two-layer composite slab, *J. Aero/Space Sci.* **27,** 8, 633–634 (Readers' Forum), Aug. 1960.

975. Tautz, H., Determination of thermal conductivity of vulcanized rubbers in relationship to elongation (in German), *Experimentelle Technik der Physik* **7,** 1, 1–14, 1959.

The article in the main is devoted to the description of a test apparatus for measurement of the thermal conductivity of vulcanized rubber filaments under different degrees of elongation. The experimental method is also described and some experimental results are presented. The latter, though few, are cited as the basis for the author's conclusion that the theory of interrelationship of structural changes due to stretching and thermal conductivity, which is briefly outlined in the article, has been substantiated, and that the thermal conductivity of high-order polymers increases considerably when those changes occur.

The apparatus, very cleverly constructed, allows changing the length of the specimen without an interruption of the test. The specimen is inserted in series with thermal resistance of known value. Temperature is read at three points: end of specimen, junction of specimen and resistance, end of resistance. The heat flow through the resistance is then calculated, and the thermal conductivity of the specimen computed, since the heat flow through the specimen is equal to that through the resistance and the specimen's length and cross-sectional areas are known. The tests are conducted in a vacuum chamber. Some heat, however, escapes through the surfaces of the specimen to the surrounding walls. For this reason all data are presented in relation to the thermal conductivity of the unstretched rubber compounds rather than in absolute values. The error is estimated to be ± 15% max. A method is presented to establish a relation between relative cross section and relative elongation of the specimen. The author has tested eight rubber compounds. The graphs of relative thermal conductivity versus relative elongation are presented for these materials. I. A. Black, USA

976. Kessler, A., Heating of plates and finite rods with internal heat generation in the one-dimensional case (in Czech), *Aplik. Mat., Ceskoslov. Akad. VED* **3,** 3, 190–222, 1958.

The differential equation concerning the problem given in the title is solved for symmetrical cases of heat flow with the following boundary conditions: the temperature at the end of the rod is a prescribed function of time, the rate of flow of heat from the end of the rod is either a prescribed function of time or a function of the temperature at the end of the rod and equal temperatures at the surface of separation of two plates of different conductivities with continuous heat flux. It is shown that many of the cases having the stated boundary conditions can be considered as special cases of three fundamental ones, the solutions of which converge to that of the special cases for definite values of appropriate parameters. The solutions of the three fundamental cases are obtained by means of the Laplace transformation and the results are given in dimensionless form by introducing suitable dimensionless criteria and parameters. F. Krupka, Czechoslovakia

977. Tirskii, G. A., Two exact solutions of Stefan's nonlinear problem, *Soviet Phys.-Doklady* **4,** 2, 288–292, Oct. 1959. (Translation of *Doklady Akad. Nauk SSSR (N.S.)* **125,** 2, 293–297, Mar./Apr. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

One-dimensional problems of heat flow involving propagation of a phase change in a medium whose thermal parameters vary with temperature are formulated in terms of nonlinear integral equations for cases (a) fixed constant-temperature heat source, (b) ablation of material and constant rate of heat supply at phase boundary. General solution of (a) is given for uniform initial temperature, when diffusivity is independent of temperature (conductivity, etc. still varying). Solution of (b) is also derived, but initial conditions now are prescribed by form of variation of parameters, e.g. exponential when diffusivity is constant.

S. Paterson, Scotland

978. Graff, W. J., Thermal conductance across metal joints, *Mach. Design* **32,** 19, 166–172, Sept. 1960.

The thermal conductance of the joint, h, is defined as the heat flow per unit area, per unit temperature difference across the joint. It is shown that a dimensionless conductance $hp/k\rho$, in which k and ρ are the thermal conductivity and the density of the metal and p is the pressure across the interface, may be correlated with a dimensionless pressure p/B in which B is the Brinell hardness of the metal. Log-log plots are substantially linear. Experimental results collected from published work give a series of lines having approximately the same slope, but these lines are displaced from one another because of differences in surface roughness. A table indicating the degree of roughness to be expected from various finishing methods is given. It is shown how this information can be used in design calculations.

R. A. W. Hill, Scotland

979. Raychaudhuri, B. C., Thermal diffusivity of a roof slab from in situ temperature measurements, *Proc. Indian Acad. Sci. (A)* **51,** 5, 258–264, May 1960.

Book—980. Lin, C. C.; editor, Turbulent flows and heat transfer (High Speed Aerodynamics and Jet Propulsion Vol. 5), Princeton, New Jersey, Princeton University Press, 1959, xv + 549 pp. $15.

This book is the fifth of a twelve-volume series on High Speed Aerodynamics and Jet Propulsion published by the Princeton University Press. It concerns mainly the interrelated problems of turbulent flow and heat transfer. All nine sections are prepared by celebrated authors in their respective fields.

H. L. Dryden presents a lucid discussion of the complex phenomena of transition from laminar to turbulent flow, in Section A. It begins with a description of transition in longitudinal flow over a flat plate, and is followed by a discussion of the effect of pressure gradient, curvature, surface roughness and waviness, and intensity of free-stream turbulence on transition Reynolds number. Turbulence originates in a random fashion at localized spots and, in general, laminar instability is not a factor. Included in the discussion are transition in shear or vortex layers, in pipes of circular and noncircular sections, transition on elliptic cylinders, airfoils, bodies of revolution, transition in flow between rotating cylinders, near rotating discs, at jet boundaries and the influence of heat transfer on transition at subsonic and supersonic speeds.

As a result of the theoretical and experimental study on the stability of laminar flow, considerable progress has been made in the understanding of the mechanism of breakdown of laminar flow. However, no mathematical theory of the transition process itself is available. The problem of transition is the problem of the origin of turbulence. Linearized theory for the instability of laminar flow could describe the beginning of the process leading to transition when the disturbances are small. It can not describe the transition process which is the result of the nonlinear character of the equations describing the motion. Progress in this direction depends very much on progress in the study of nonstationary solutions of Navier-Stokes equations.

Section B treats the general subject of turbulent flow with emphasis placed on the characteristics of mean flow. It is authored by G. B. Schubauer and C. M. Tchen.

Starting from the well-known conservation principles, authors develop equations of continuity, momentum, kinetic energy and equation of energy and enthalpy for the turbulent motion of a compressible fluid. These equations are then simplified for boundary-layer flow, and some simple relations between pressure, velocity and temperature distributions are deduced. To achieve a deeper understanding of the process, some statistical foundation of the transport mechanism is introduced. It is shown that Reynolds analogy can be better perceived as a consequence of application of statistical methods.

Skin friction theories for a compressible boundary layer are briefly treated and comparison is made with experimental data. Comprehensive discussion is given for theories relating to velocity profiles in an incompressible, turbulent boundary layer, first without and then with pressure gradient. For the former, authors consider the power law, Prandtl's law of the wall, Kármán's velocity-defect law and the logarithmic law.

Three fairly distinct regions can be recognized in turbulent boundary layers. First, there is the laminar sublayer which is 0.001 to 0.01 of the total layer thickness. Beyond this is a turbulent region which extends to 0.1 to 0.2 of the layer thickness, where the logarithmic law is valid. These comprise the "wall" or "inner" region. The mean flow is virtually unaffected by pressure gradient, and a unique relation exists between the velocity and wall shear. This region is also characterized by short time response and rapid adjustment to local conditions. In the outer region which constitutes 0.8 to 0.9 of the layer, mixing is relatively free and the velocity profile is affected by pressure gradient. A universal representation on the basis of velocity defect law is not possible.

In "free" turbulent flow such as jets, wakes and mixing zones between streams, the velocity profile becomes similar when fully developed state is attained. Laws of mean spreading and decay could be deduced from conservation equations of momentum, heat and matter. Specification of the turbulent transport process in terms of mixing-length theory, which assumes a gradient type of transfer, has been shown to be not completely adequate. A comparison is made of the several velocity distribution formulas for jets and wakes with observations, together with a discussion of the effect of density difference, compressibility and axial motion of surrounding air on jets. Finally, on the subject of turbulent structure of shear flows, authors restrict the presentation to a listing of references.

Section C, prepared by C. C. Lin, deals with statistical theories of turbulence, mainly limited to the homogeneous case. A basic quantity in applying statistical averages is the frequency distribution function. However, theories concerning it have not been developed to a usable stage and the conventional approach is to consider correlation functions which can be more readily determined by measurement. The statistical correlation of velocity fluctuations at two points is the most commonly used quantity. Another useful approach for describing a fluctuating field is the energy spectral representation introduced by G. I. Taylor. The spectral theory and the correlation theory are intimately connected by mathematical transformations, a derivation of which for the one-dimensional case is given in detail.

The dynamics of isotropic turbulence is governed by the Navier-Stokes equations of motion. A fundamental difficulty arises when one attempts to deduce equations for correlations of a given order. Higher-order correlations are invariably brought in due to non-linear terms in the differential equations. In practice, additional assumptions based on physical considerations are usually introduced. Author presents a lucid discussion of the many physical aspects of the theory of homogeneous turbulence. Included are the spectral interpretation of Loitsiansky's invariant for large-scale turbulent motion, Kolmogoroff's theory of locally isotropic turbulence, the hypothesis of self-preservation of correlation function, etc. Some experimental evidences for the various laws of decay are given.

Turbulent diffusion is discussed in terms of Taylor's theory of continuous movements. It is shown that the concept of diffusion coefficient is justified for long diffusion times. For a more complete description of the diffusion process, one needs to consider the joint statistical behavior of a large number of fluid particles. This and other aspects of the problem, including temperature fluctuations in homogeneous turbulence, magneto-hydrodynamic turbulence, dynamic effects of turbulent motion, etc., are briefly touched upon.

Conduction of heat is the topic of discussion in Section D. It was written by M. Yachter and E. Mayer. The material was selected on the basis of its immediate applicability to heat flow in combustion chambers, nozzles, turbine blades, skins of high-speed aircraft, etc. Emphasis is placed on simple, yet representative, model problems leading to analytical results. This allows an insight into the role played by geometry, heat-transfer coefficients and thermal properties.

Authors begin by summarizing the general mathematical formulation of the heat-conduction problem. Particularly note-worthy is the proof given for the orthogonality of the eigenfunctions weighted by $\sqrt{cp}$ where cp is the volumetric heat capacity of the subdomains of the solid under consideration. Reviewer noted that this rather elegant proof was not included in the classical work on "Conduction of heat in solids" by H. S. Carslaw and J. C. Jaeger (1959).

Three separate chapters are devoted to transient linear heat flow problems in homogeneous slabs and semi-infinite solids; to radial heat flow in homogeneous, hollow cylinders; and to linear heat flow in composite slabs. The problem of thermal shielding and design criterion for minimum weight are discussed in the light of solutions obtained for composite slab. A brief discussion is also given for problems involving variable thermal properties and surface melting and erosion.

Section E concerns convective transfer and friction in flow of liquids. It consists of two chapters. The first, written by R. G. Deissler, describes the calculation of fluid friction and heat transfer for turbulent flow in smooth passages. It is pointed out that any attempt of this nature based on conservation laws *alone* has not yet been practical. Physical assumptions connecting eddy diffusivity for momentum transfer to mean flow and to that for heat transfer would have to be introduced. These are done in the light of phenomenological theories of turbulence expounded in Section B. Several cases presented include heat transfer and friction in fluids of various Prandtl numbers for fully developed flow, for entrance region, for flow in circular and noncircular conduits and for fluids of constant and variable properties. In most cases, experimental results are shown to be in good agreement with theoretical predictions.

Chapter 2 of this Section presents a survey of problems in boiling heat transfer. It was prepared by R. H. Sabersky. Attention is directed toward nucleate boiling. A principal aim of numerous investigations is the prediction of maximum rate of heat transfer under prescribed conditions. This, however, has not been successful. Topics briefly discussed include the nucleation process, various factors influencing growth and collapse of bubbles, effect of bubble motion on heat transfer and frictional pressure drop. Reviewer noted that this survey unfortunately omits the rather significant work of Plesset and Zwick, Forster and Zuber on bubble growth.

E. R. van Driest is the author of Section F which deals with convective heat transfer at high velocities. Starting from a general discussion of the basic problems of heat transfer in compressible boundary layers, author presents in Chapter 1 a survey of the theoretical results and current status of experimental knowledge in laminar, turbulent and transitional boundary layers. Mathematical analysis is outlined for laminar flow over flat plate, based on an

extension of Crocco's procedure. For turbulent boundary layer, the momentum equation is not amenable to solution and the approximate integral method is used to obtain skin friction based on velocity profiles derived from mixing-length hypothesis. Numerical results for recovery factor, Reynolds analogy factor and local heat-transfer coefficient are given. Comparison is made between theory and experiment. The laminar recovery factor is shown to be dependent on Mach number and, in contrast, the turbulent recovery factor is insensitive to Mach number changes. A simple procedure is described for predicting stagnation point heat transfer over cylindrical and spherical surfaces which could be used even if appreciable dissociation occurs.

Chapter 2 of Section F considers some application of theory to aerodynamic heating of high-speed vehicles, heat transfer in rocket motor and the influence of dissociation.

In Section G, S. W. Yuan presents a critical review of the fundamental aspects of cooling by protective films and briefly compares transpiration and film cooling techniques. Heat transfer in transpiration-cooled boundary layer and pipe flow are discussed in terms of basic conservation equations. An interesting result obtained from studies of nonisothermal laminar flow over a plate with coolant injection is that both friction and heat-transfer coefficient decrease with increase in coolant injection. For pipe flow, the effect of fluid injection at wall is to accelerate the main stream velocity and hence to increase wall friction. Analogy between heat and momentum transfer does not exist in porous wall cooling of pipe flow.

Some comparison between theory and experiment was made and methods of manufacturing porous metals are briefly described.

The final two sections, H and I, deal, respectively, with the basic physical laws of thermal radiation and engineering calculations of radiant heat exchange. The former is written by S. S. Penner and the latter by H. C. Hottel. Theoretical calculations of gas emissivities require determination of spectral absorption coefficient in terms of atomic or molecular parameters. For diatomic gases, basic spectroscopic studies have been carried to a point where useful absolute calculations and extrapolations to high temperatures are feasible. Such is not the case for polyatomic gases. Section H contains a brief survey of basic laws of thermal radiation, including those for distributed radiators.

Nearly all the material in Section I can be found in Chapter 4 of McAdam's "Heat transmission," 3rd ed. Reviewer noted that the network method of analysis as pointed out by Paschkis [*Elektrotech. u. Maschinenbau* **54**, p. 617, 1936] and more recently generalized by Oppenheim [*ASME Trans.* **78**, p. 725, 1956] was left out both in the discussion and in the cited references. In view of the simplicity and straightforwardness of the method, it may prove to be a useful addition in future editions of the book.

The excellent qualities of the book far outweigh the minor deficiences that have been noted. In all nine sections, emphasis has been laid on clear description of the physical process and mathematical analysis whenever possible. It will retain its importance for many years to come and, beyond doubt, it is a most valuable addition to literature in the field.

B. T. Chao, USA

981. Goroff, I. R., An experiment on heat transfer by overstable and ordinary convection, *Proc. Roy. Soc. Lond.* (*A*) **254**, 1279, 537–541, Mar. 1960.

Because the Prandtl number is low, a layer of mercury heated from below and subject to uniform rotation first becomes unstable *via* a state of purely oscillatory motions (overstability). Generally, for a Rayleigh number much in excess of the value at which overstability sets in, the system becomes unstable also for ordinary stationary *aperiodic* motion (convection). Chandrasekhar has suggested that, because overstable motions may be ineffective in transporting heat, it might be possible to detect the onset of ordinary convection even when it is superimposed on finite amplitude overstability. Experimental determinations of the Nusselt number (heat-transfer coefficient) as a function of Rayleigh number at three values of the Taylor number (which measures the rotation rate in appropriate units) confirm Chandrasekhar's surmise quantitatively.

R. Hide, England

982. Van Wijk, W. R., Derksen, W. J., and Goedkoop, H., On turbulent heat exchange in the air near the ground (in English), *Physica* **25**, 12, 1259–1270, Dec. 1959.

An original method based on the propagation of a heat impulse has been developed to compute the turbulent exchange coefficient from observations. The impulses occur when cloudy and sunny periods alternate. The theory for the propagation of the pulse has been developed assuming the eddy conductivity to increase linearly with height. Observations of the temperature variation with time at two heights were compared with theoretical curves yielding fair agreement for eddy conductivities considerably below those obtained in other investigations. The comparison was considerably simplified with the use of Laplace transforms.

In reviewer's opinion it would be highly desirable to repeat this type of experiment under conditions of horizontal hogomogeneity and also to give a discussion of the limitations imposed by the assumption of a linear increase with height of the turbulent exchange coefficient.

J. A. Businger, USA

983. Senftleben, H., and Schnabel, P., Heat transfer between concentrical cylinders in liquids and gases (in German), *Z. Angew. Phys.* **11**, 11, 428–432, Nov. 1959.

Heat transfer by free convection between concentrical cylinders has been solved with a simple interpolation formula connecting the authors' theoretically derived and tested relations for the limiting cases of free convection around a single cylinder and molecular conduction between two concentrical cylinders with such a spacing that free convection is just prevented. Observations are well described for horizontal cylinders. For vertical cylinders not enough observations were available to test the formulas adequately. The results are, as customary, expressed in dimensionless parameters derived from similarity conditions.

J. A. Businger, USA

984. Kruglov, S. A., and Skoblo, A. I., Investigation of convection heat exchange between a granular material and a flow of gas (in Russian), *Khimiya i Teknol. Topliv i Masel* no. 3, 23–30, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5226.

This is an experimental investigation of convection heat exchange in a counter current of granular material with air, with the regime of heating established. The relations of Nusselt numbers N and Reynolds numbers R are found on the basis of experimental data with different conditions of heat exchange: a moving dense layer of grains, free-falling particles, and for an overflowing layer of granular material. It was found that in the process of convection heat exchange in a moving dense layer in the R zone from 40 to 610 two principles of heat exchange are in operation, corresponding to a transition and to a turbulent region of the gas flow in the layer. The transition of the first to the second state is determined by the R value of 200. Data are given for the hydrodynamic resistance.

O. S. Vorob'ev

Courtesy Referativnyi Zhurnal, USSR

985. Morton, B. R., Laminar convection in uniformly heated vertical pipes, *J. Fluid Mech.* **8**, 2, 227–240, June 1960.

Two main cases are considered: fluid flowing (1) up a uniform vertical pipe heated from outside, or down a cooled pipe, (2) up a cooled pipe, or down a heated pipe. Flow is assumed laminar, axially symmetrical, independent of height, with heat input accordingly. In (1) as Rayleigh number (horizontal temperature gradient) increases for given axial imposed pressure gradient flow changes from parabolic Poiseuille profile to one with flattened and

eventually hollowed center. Temperature profile only becomes flattened. In (2) flow in center increases rapidly with Rayleigh number and at a critical value "runs away" (i.e. becomes infinite); steady flow thus becomes impossible, but what happens is only discussed qualitatively. The solutions are necessarily incorrect in this case because no axial pressure gradient can be imposed in accordance with the assumptions of a pipe of finite length. R. S. Scorer, England

986. Kutateladze, S. S., Borishanskii, V. M., and Novikov, I. I., Heat exchange in molten metals (in Russian), *Atomnaya Energiya* **4**, 5, 422–436, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5222.

A review is given of the principal works of Soviet and foreign authors on the study of heat exchange between solid surfaces and a flow of molten metal. Results of experiments are scrutinized; these were made to study the heat emission to the liquid metal during its flow through long and short tubes, flat slots, during longitudinal flow over an assembly of bars and plates and during the transverse flow over cylinders. The significant reciprocal divergence of the experimental data, reaching as much as ~ 100%, appears to be characteristic. For the calculation of heat emission to molten metals in commercial tubes at Peclet P numbers from 300 to 15,000 and Reynolds numbers $R > 10{,}000$ the following formula for Nusselt's number is recommended $N = 3.3 + 0.014\,P^{0.8}$ or $N = 5 + 0.0021\,P$. The same formulas can be used in a flow in an annular clearance by introducing the equivalent hydraulic diameter equal to double the width of the clearance. For values of P between 20 and 300 the approximate formula given here is recommended $N = 0.7\,P^{1/2}$. The increase in heat emission, in short, can be computed, it is recommended, by using the multiplier

$$\varepsilon_l = 1.72\left(\frac{D}{L}\right)^{0.16}$$

An examination is made of the heat emission during free convection and condensation of vapor of the molten metal. Questions are discussed connected with the boiling of liquid metals, and also with the effect of wetting capacity on the hydraulic resistance and the intensity of the heat exchange; it is noted that the boiling of the metals is subordinated generally to the same principles as in the case of nonmetallic liquids. A more detailed investigation of the questions linked with the heat exchange in liquid metals and its application is to be found in the studies of S. S. Kutateladze, V. M. Borishanskii, I. I. Novikov, O. S. Fedunskii in "Liquid metal heat carriers" [*Atomnaya energiya* 1958, Suppl. no. 2].

N. P.-S.

Courtesy Referativnyi Zhurnal, USSR

987. Greenbaum, M., Transistor heat sink calculations, *Electronics* **33**, 32, 66–68, Aug. 1960.

988. Sparrow, E. M., and Siegel, R., Unsteady turbulent heat transfer in tubes, *ASME Trans.* **82** C (*J. Heat Transfer*), 3, 170–180, Aug. 1960.

Flow in a tube is assumed to be steady and fully developed. Downstream of a fixed position the wall temperature changes to another value independent of distance. A basic solution is obtained for a sudden temperature increase and a superposition technique is outlined by which any time-dependent wall temperature can be analyzed. This is applied to a steady linear increase. Numerical solutions of a linearized form of the energy equation are obtained for Prandtl numbers of 0.7, 10 and 100 at a Reynolds number of 100,000 and for a $Pr = 0.7$ at $Re = 500{,}000$. Method differs from conventional solutions in that a local heat-transfer coefficient dependent on local temperatures is used in place of constant value. Results show large differences in heat-transfer rate in the transient region, there being much larger rate variations for the more precise solution. Deviations are not so great for linear wall temperature variation. W. D. Baines, Canada

989. Sprinks, T., A review of work relevant to the study of heat transfer in hypersonic separated flows, Univ. Southampton, Dept. Aero. & Astron. Rep. no. 138, 30 pp., June 1960.

990. Henderson, A., Jr., and Swalley, F. E., Effects of air contamination in a helium tunnel, NASA TN D-406, 26 pp., June 1960.

The effects of contamination of helium by air upon static-pressure, total-pressure, heat-transfer, and temperature measurements have been investigated in the 2-inch helium tunnel at the Langley Research Center. Within the scope of the tests, even a small amount of air is shown to affect these measurements. The heat-transfer and temperature measurements were made on a 26.6° half-angle cone and demonstrated the effects of contamination qualitatively. The wall static and centerline pitot pressures show that if the contaminating air is held to less than about 0.2% by volume, the error in indicated Mach number is less than 1% as calculated from the Rayleigh pitot equation. The corresponding errors in wall static and centerline pitot pressures are about 1.7 and 0.4%, respectively. From authors' summary

991. Eckert, E. R. G., and Tewfik, O. E., Use of reference enthalpy in specifying the laminar heat-transfer distribution around blunt bodies in dissociated air, *J. Aero/Space Sci.* **27**, 6, 464–466 (Readers' Forum), June 1960.

992. Otake, T., and Tone, S., Heat transfer mechanisms in stirred bed, *Techbnol. Rep. Osaka Univ.* **10**, 231–240, Jan. 1960.

Authors studied the heat transfer in the stirred bed to obtain information useful in the design and operation of a reactor containing powder. The temperature profiles were actually measured and some values of effective thermal conductivities and wall heat-transfer coefficients in the stirred bed were evaluated. The heat transfer mechanisms in the stirred bed were found to be analogous to those in the packed beds. From authors' summary

993. Sparrow, E. M., and Gregg, J. L., Nearly quasi-steady free convection heat transfer in gases, *ASME Trans.* **82** C (*J. Heat Transfer*), 3, 258–260 (Tech. Briefs), Aug. 1960.

Paper concerns free convection from surface over which temperature is constant in space but variable in time. Practical assumption often made is that conditions are instantaneously steady, and steady-state equations are applied, even though this involves some error. Object of paper is to derive criterion for determining when this procedure is permissible within specified limits of error. Analysis is based on boundary-layer forms of equations for conservation of mass, momentum, and energy for buoyancy-induced flow of ideal gas over vertical plate. Solutions for temperature and velocity distributions, made in form of series expansion about quasi-steady state, lead to criterion for time required after some event before steady-state equations are permissible. Since criterion is developed for laminar flow, it should be on safe side for turbulent flow. Although not supported by direct experimental evidence, reviewer believes criterion should be considered suitable unless and until superseded by something better.

C. W. Smith, USA

994. Schmidt, E., Heat transfer by natural convection in fluids in critical condition (in German), *Inter. J. Heat and Mass Transfer* **1**, 1, 92–101, June 1960.

Experiments on natural convection of ammonia and of carbon dioxide in vertical tubes heated near the bottom and cooled near the top show that at a given rate of heat transfer an extremely low temperature gradient is obtained near the critical point of the fluid. The inner diameter of the tube was varied between 2 and 4 cm, the tube length between 34 and 200 cm, and the rate of heat transfer between 45 and 410 Watts. The axial transmission of heat by natural convection was represented by an effective thermal conductivity; a maximum value of 14 kw/cm°C was found for the cen-

tral part of the largest tube. The experimental data are explained by the increases in the specific heat and in the coefficient of thermal expansion up to infinity at the critical point.

H. A. Vreedenberg, Holland

995. Yang, K.-T., Possible similarity solutions for laminar free convection on vertical plates and cylinders, *ASME Trans.* **82** E (*J. Appl. Mech.*), 2, 230–236, June 1960.

An analysis is made to find the particular space and time variations of the wall temperature which lead to similar solutions of the laminar boundary-layer equations. Numerical solutions of the governing differential equations were not carried out, but are promised later. Many of the newly possible similarity solutions possess interesting properties along the line $x = 0$ (i.e., at the leading edge). In particular, the velocity and temperature distributions in the fluid passing the leading edge are not uniform, and the velocity is not zero, as is usual in free convection. Reviewer feels that perhaps these cases more properly belong to the category of combined forced and free convection, rather than to pure free convection.

E. M. Sparrow, USA

996. Palm, E., On the tendency towards hexagonal cells in steady convection, *J. Fluid Mech.* **8**, 2, 183–192, June 1960.

Equations of motion for a liquid of viscosity and density varying with temperature and constant thermal conductivity are linearized for motion between parallel planes at fixed temperatures but with no shearing stress. The variation of viscosity is made sinusoidal in the vertical so that the equations may be satisfied by velocities exhibiting a cellular pattern and represented by series of sinusoidal terms. The Rayleigh number for the onset of convection is shown to be slightly less than for a uniform viscosity of the same mean value. There are an infinite number of simultaneous equations for the amplitudes of the various waves but two are singled out because they are initially the most unstable. If the most important terms are considered they interact with one another in such a way that the third-order terms are damping and act with the terms representing conductivity so as to produce a steady state in which the two waves have amplitudes such that hexagonal cells result. This is the first analytical treatment of a well-known experimental result and the method can probably be applied to investigate effects of variable thermal conductivity.

R. S. Scorer, England

997. Dumitrescu, L., On heat-transfer in free-molecule flows (in English), *Rev. Mécan. Appl.* **4**, 2, 237–247, 1959.

Heat transfer is investigated within bodies which move at high velocities through a rarefied gas. It is shown that owing to the great differences between the energy received by the front and rear parts of the body, a heat flow is established which leads to nonuniform temperatures in the body. The assumption of constant temperature throughout, previously made in studies dealing with free-molecule flows, holds true only for bodies made of materials having an infinite thermal conductivity. In the case of structures covered by a thin metallic shell, under which there is an insulating layer, the temperature nonuniformity may be appreciable. Analysis of the unsteady-state heat flow, in a simple case, shows that, in the first minutes after the beginning of the movement, very high temperature gradients arise in the body; then a sort of temperature wave is propagated through the body, attenuating the temperature nonuniformity, and finally establishing the steady-state temperature field.

H. Mirels, USA

998. Adams, E. W., The thickness of a melting ablation-type heat shield, *J. Aero/Space Sci.* **27**, 8, 620–621 (Readers' Forum), Aug. 1960.

999. Hartnett, J. P., Masson, D. J., Gross, J. F., and Gazley, C., Jr., Mass-transfer cooling in a turbulent boundary layer, *J. Aero/Space Sci.* **27**, 8, 623–624 (Readers' Forum), Aug. 1960.

1000. Usiskin, C. M., and Sparrow, E. M., Thermal radiation between parallel plates separated by an absorbing-emitting nonisothermal gas (in English). *Inter. J. Heat Mass Transfer* **1**, 1, 28–36, June 1960.

Given two parallel plates, at same or different temperatures, with an absorbing-emitting gas between them which may have nonuniform temperature distribution and possibly a heat source. What are radiation effects ascribable to gas? Well-known elementary solutions neglect gas effects or allow only for absorption of some of plate-to-plate radiation; others ignore *local* absorption-emission processes; still others give solution based on assumption of *finite-size* gas volumes. Present paper gives solution based on *continuous* temperature variation, though ignoring conduction and convection. Procedure is to equate radiant energy emitted by elementary volume dV to energy absorbed by emission from plates, body of gas, and heat source, if any. Suitable expression of these quantities leads to integral equation which, when numerically integrated, gives distribution of emissive power (or temperature) in gap. Results, presented in graphical form, show that, in general, temperature distribution across gap will be fairly uniform, both with and without heat source, so that heat conduction effects would be confined mostly to vicinity of plates if conductivity is low. For a fixed plate spacing, and no heat source, increase of heat-absorption coefficient decreases heat transfer—a fact which may be useful in choosing gas to minimize heat transfer. Paper should be of interest to gas turbine, rocket, and furnace designers.

C. W. Smith, USA

1001. Parkes, E. W., Influence coefficients for radiation in a circular cylinder, AFOSR TN 60-415 (Stanford Univ., Dept. Aero. Engng. no. 92), 11 pp., Mar. 1960.

Radiation with absorption and reflection on the interior surface of an infinite circular cylinder is treated. The basic problem considered is the determination of the intensity of radiation absorption as a function of angular position on the surface when there is an initial emission of radiation that is distributed arbitrarily with respect to angular position. Tables are presented of an influence coefficient that is proportional to the intensity of absorption of radiation that was initially emitted by a line source at a given angular position on the interior of the cylinder. This influence coefficient is presented as a function of angular position relative to the source as well as of the absorptivity of the surface.

J. E. Plapp, USA

1002. Batishshev, Ya. F., Heat emission from the wall to the gases in tubes with fittings of complex parameters (in Russian), *Trudi Novovberk. Politekhn. In-ta* **70/84**, 45–63, 1957; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 2704.

A relation of the form given below is recommended for calculating the heat emission from the walls to the various gases in a tube with a fitting of arbitrary geometrical form, made of materials with different heat conductivities and roughness

$$\overline{N}_D(D/d)^m = f(\overline{R}_d)$$

This was obtained as the result of experiments by the author for the case of heat emission to the air in a tube fitted with smooth steel balls. Here N is Nusselt number, R is Reynolds number, D is the diameter of the tube, d is the calculated dimension of the fitted modulus, m is an indicator which is a constant for the determined interval R. Data of experiments by Colbourn, Levi, and Levi and Grummer are used to justify the calculations; these data were converted by the author into the proper form with consideration for systematic experimental error, and up to date values for the heat capacities of gases.

E. A. Nakhapetyan

Courtesy Referativnyi Zhurnal, USSR

1003. Schneider, P. J., Radiation cooling of finite heat-conducting solids, *J. Aero/Space Sci.* **27**, 6, 546–549 (Readers' Forum), June 1960.

1004. Poletavkin, P. G., Hydraulic resistance at surface boiling of water (in Russian), *Teploenergetika* 12, 13–18, Dec. 1959.

Surface boiling in subcolled liquid, which may occur in high-flux water-cooled nuclear reactor, results in a considerable increase of resistance to liquid flow. Previous publication on the subject failed to provide working formulas for pressure loss in this region.

Author's experimental results obtained for a wide range of operating variables are presented, and compared with results of other investigators. It is shown that all results when grouped in dimensionless parameters agree closely with formulated empirical equations relating the ratio of pressure drop in flow of subcooled liquid with surface boiling to that in isothermal flow with Reynolds number, heat flux, temperature of subcooling, and liquid pressure.

Economy of reactor is defined as the ratio of rate of heat transfer to pumping power, and it is proved that at $Re > 3.5 \times 10^4$ reactors with surface boiling are more economical than those with convective heating.

Reviewer believes that this is a very valuable and conclusive paper. S. Smoleniec, South Africa

1005. Labunstov, D. A., Heat exchange at bubble boiling of liquid (in Russian), *Teploenergetika* 12, 19–26, Dec. 1959.

This is an analytical investigation of stagnant pool nucleate boiling. Analysis, based on thermodynamic and physical properties of fluids, concerns formation and growth of vapor bubbles in microcavities of heating surface submerged in a surface wetting liquid.

Assuming conical shape of microcavity author develops equations relating a probability of nucleation with the cone angle for varying liquid contact angle. This is followed by formulation of an expression for the speed of bubble growth in terms of its radius, presented also in dimensionless form. Using the initial speed of growth and minimum bubble radius a Reynolds number is defined which is a measure of disturbance produced by nucleation in the liquid directly adjacent to heating surface. Postulating that this disturbance is the main cause of intensive heat transfer in nucleate boiling, a dimensionless equation for the heat transfer in this region is derived.

Reviewer believes that the above analysis, which leads to formulation of criteria of similarity for nucleate boiling heat transfer, constitutes a valuable contribution to knowledge in this field. S. Smoleniec, South Africa

1006. Sieraski, R. J., and Machwart, G. M., A nomograph for boiling temperature by the Meissner method, *Indust. Engng. Chem.* **52**, 10, 869–870, Oct. 1960.

The nomograph can be used to determine surface tension, molar refraction, or density at different temperatures as well as determining boiling points. From authors' summary

1007. Davidson, J. F., and Schuler, B. O. G., Bubble formation at an orifice in a viscous liquid, *Trans. Inst. Chem. Engrs.* **38**, 3, 144–154, 1960.

A theory of bubble formation based on the motion of a bubble in a viscous liquid has been developed. The theory gives the volume of gas bubbles formed at an orifice in a viscous liquid for both constant gas flow and constant gas pressure.

Experiments were carried out with liquids of high viscosity (500–1040 cp). Good agreement with theory was obtained over a large range of gas flow rates (0–50 ml/s).

From authors' summary

1008. Styrikovich, M. S., and Nevstrueva, E. I., Investigation of vapor-content distribution in boiling boundary layers by the beta-radioscopy method, *Soviet Phys.-Doklady* **5**, 1, 58–61, July/Aug. 1960. (Translation of *Dokladi Akad. Nauk SSSR (N.S.)* **130**, 5, 1019–1022, Jan./Feb. 1960 by Amer. Inst. Phys., Inc., New York, N. Y.)

1009. Scala, S. M., and Vidale, G. L., Vaporization processes in the hypersonic laminar boundary layer (in English), *Inter. J. Heat Mass Transfer* **1**, 1, 4–22, June 1960.

An analysis of the phenomenon of vaporization is presented for hypersonic flight conditions, and numerical solutions are presented for mass transfer at the stagnation point of an axially symmetric vehicle. These results were obtained by solving the pertinent boundary-layer equations for diffusion, convection and thermal exchange, subject to the appropriate physicochemical constraints arising from the kinetics of vaporization.

In addition, a universal solution is given, in terms of the most significant independent parameters, which defines the flight regimes where the vaporization process is diffusion controlled, kinetically limited, or both.

Utilizing the general correlation formula derived herein, one may estimate the rate of vaporization of an arbitrary material, subject to hypersonic flight conditions, provided only that one has an independent knowledge of certain minimum physicochemical data.

From the authors' summary by K. Stewartson, England

1010. Konovalov, V. I., Heat transfer from the condensing steam to the turbulent water stream (in Russian), *Izv. Vyssh. Uchebn. Zavedenii, Energetika* no. 1, 97–100, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5220.

A simplified physical model is proposed to follow the process of condensation and heat exchange during the spreading of a turbulent water stream into a space filled with steam, applicable to the conditions governing the work of a stream-lined mixing heater. No experimental data are furnished.

O. V. Yakovlevskii
Courtesy Referativnyi Zhurnal, USSR

1011. Ferraiolo, G., Calculation of the height of an atmospheric cooling tower (in Italian), *Ingegnere* **32**, 2, 101–110, Feb. 1958.

The equation for the heat transfer between the water, which is to be cooled, and the air allows one to obtain an expression for the height of the tower. This expression contains an integral which can easily be calculated by using an empirical equation for the enthalpy of air, saturated with water vapor, as a function of the temperature.

The results obtained are sufficiently accurate for normal applications. E. A. Brun, France

1012. Shcherbakov, E. Ya., and Bregina, A. Yu., Investigation of heat and humidity transfer in combination with the general circulation of the atmosphere (in Russian), *Trudi Gl. Geofiz.* no. 70, 3–37, 1957; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5264.

The characteristics are given of the changes in the humidity and heat content of air masses during their travel over the Eurasian continent, and a quantitative evaluation of the transfer of heat, humidity and horizontal dissipation of the atmospheric particles of the flow was made. The following constituted the initial materials employed: weather charts at earth level, charts for AT 850, 700 and 500 mb and the original aerological observations for 1951, 1953 and a part of 1948. In selecting the synoptic processes for investigation, G. Ya. Vangenheim's classification of types was utilized. For the purpose of solving the problem set trajectories were drawn of the flows of air particles at the AT 850, 700, 500-mb levels which enabled determinations to be made of: the regions of withdrawal of atmospheric masses, the main routes

of their transfer and velocities, the mean accretion of particles in the different regions of Eurasia, the variations in heat content of the moving masses, the mean horizontal dissipation of particles at different levels. The velocity of transfer of humidity and heat was determined for a column of air five kilometers high with a cross section of 1 cm², and was computed by means of the formulas,
for humidity:

$$0.10\,u_{\text{earth}} + 0.64\,u_{850} + 0.20\,u_{700} + 0.06\,u_{500} \qquad [1]$$

and for heat:

$$0.05\,u_{\text{earth}} + 0.40\,u_{850} + 0.35\,u_{700} + 0.20\,u_{500} \qquad [2]$$

where u is the velocity of transfer to the corresponding level. The coefficients in formula [1] are assigned with consideration for the distribution by altitude of the humidity and wind velocity; while in formula [2], with consideration for the distribution of masses in layers and wind velocity. The general amount of transfer of humidity for the atmospheric column in a second was determined as the product of the humidity content computed for the column and the velocity of transfer. The territories comprising Europe, Western Siberia, the Near and Middle East were divided into six zones. The first and second, situated north of the 60th parallel and bounded, respectively, by the 0°–60° and 60°–120° east longitudes formed the Northern zone; the third and fourth, forming the Central zone bounded by the 50th and 60th parallel lay, respectively, in the East longitudes of 0°–60° and 60°–120°; in the Southern zone, south of the 50th parallel, the fifth and sixth zones were situated with longitudes corresponding to the other zones. The authors established the characteristics of the humidity and heat currents by differentiating in the given zones and regions, with consideration for the season of the year and the zones of withdrawal at atmospheric masses. The data are given in tables (sixteen in all) and an analysis is furnished of them.

I. V. But
Courtesy Referativnyi Zhurnal, USSR

1013. Cywin, A., Fresh water from salt water, *Mech. Engng.* **82**, 10, 57–62, Oct. 1960.

1014. Scala, S. M., Sublimation in a hypersonic environment, *J. Aero/Space Sci.* **27**, 1, 1–12, Jan. 1960.

The complex problem of hypersonic ablation has been treated including the case of sublimation of a refractory oxide. By defining a "gasification ratio" $\Gamma = \dfrac{\text{Mass rate of vaporization}}{\text{local total rate of mass loss}}$, sublimation becomes the limiting case of $\Gamma = 1$.

Going back to previous publications by the author, the rate of vaporization into gas phase is treated including equilibrium considerations and catalytic surfaces. By satisfying the conservation laws at the interface between gas and liquid phase, effective heat of vaporization, ablation rate and surface temperature as a function of T are determined and the important role of the physicochemical restraints is shown. The final evaluation shows that the total rate of mass loss decreases with increasing T.

Effect of environmental conditions on the effective heat of vaporization Q^* is treated in detail as the base for the designer's effort to keep the mass loss down. Q^* is found to be an increasing function of stagnation enthalpy, independent of body size when the ablation is diffusion-controlled and surface emissivity is small.

Paper is an expert's contribution and written clearly with the engineering applications in mind. H. J. Ramm, USA

Book—1015. Foust, A. S., Wensel, L. A., Clump, C. W., Maus, L., and Andersen, L. B., Principles of unit operations, New York, John Wiley & Sons, Inc., 1960, vii + 578 pp. $15.

This book is a text on unit operations for chemical engineering students. Contents are divided into three parts, twenty-two chapters, and four appendices. A general treatment of mass-transfer stage operations is presented in Part I. Numerical and graphical methods of calculation based on the physical model of an equilibrium stage are developed. The treatment of methods using ternary and enthalpy-composition diagrams is very informative, with good figures. The corresponding stage apparatus, e.g. bubble-cap plates, is dealt with very briefly.

Part II deals with the fundamental principles of molecular and turbulent transport of heat, mass, and momentum. Wherever possible the three transport processes are treated in a general or parallel way, and the Reynolds, Colburn, and Martinelli analogies among mass, heat, and momentum transfer are discussed. Turbulence is explained at the junior-year level. Part II ends with a chapter on interphase transfer of heat and mass.

Part III deals with the applications of transport processes. The theoretical methods are completed with empirical equations and experimental data. Treatment is in most cases limited to evaluation of transfer area required. A large chapter deals with heat transfer, including a brief description of industrial heat-exchange equipment, and a treatment of thermal radiation. As examples of simultaneous heat and mass transfer there are chapters on humidification, drying, evaporation, and crystallization. One chapter deals with fluid friction and meters, and agitation; one with pumps and compressors; one with phase separations such as classification and centrifugation. Flow through packed beds and fluidization are discussed. Line drawings and photographs of equipment are of very good quality. The appendices deal with dimensional analysis, model theory, particle-size measurements, and data.

The different methods of calculation are applied in a large number of illustrations; almost all chapters contain several problems and references.

The new and unique treatment of unit operations used by authors is somewhat confusing at the beginning, but reviewer believes it is a very good way to get a greater understanding of the subject. The book will in some parts, especially part II, be of great use to all engineers interested in heat, mass, and momentum transfer.

G. Selin, Sweden

1016. Lockard, J. L., and Weber, J. H., Spined tubes in cross-flow exchangers, *Indust. Engng. Chem.* **52**, 11, 925–928, Nov. 1960.

1017. Devyatov, B. N., Transient effects in continuously acting thick-walled heat exchangers, *Soviet Phys.-Doklady* **5**, 1, 54–57, July/Aug. 1960. (Translation of *Doklady Akad. Nauk SSSR (N.S.)* **130**, 1, 68–71, Jan./Feb. 1960 by Amer. Inst. Phys., Inc., New York, N. Y.)

1018. Turcotte, D. L., The melting of ice in a hot humid stream of air, *J. Fluid Mech.* **8**, 1, 123–129, May 1960.

By use of appropriate approximations the incompressible stagnation-point ablation rate for ice is determined theoretically. The theory includes both melting and vaporization or condensation. To verify the theory, hemispheres of ice were melted in a subsonic wind tunnel with controlled humidity. It is found that the effects of heat transfer and condensation are of equal importance in determining the melt rate. The agreement between theory and experiment is adequate.

From author's summary by T. D. Patten, Scotland

1019. Marcus, R. J., and Wohlers, H. C., A new solar furnace—design and operation, *Indust. Engng. Chem.* **52**, 10, 825–826, Oct. 1960.

Ultraviolet sunlight is concentrated and used in this solar furnace. Photochemical yields are increased by a factor of 10 over more conventional furnaces. From authors' summary

1020. Mercer, A. McD., The growth of the thermal boundary layer in laminar flow between parallel flat plates, *Appl. Scient. Res. (A)* **8**, 5, 357–365, 1959.

The problem considered is that of the heat transfer occurring at the inlet to a parallel plate channel. Instead of separating variables, the energy equation is solved, after transformation, in the form of a power series. This method supplies information concerning the initial growth of the thermal boundary layer which is not obtainable by previous methods using eigenfunction expansions. A sufficient number of coefficients of the series is computed to allow the present solution to be joined to the asymptotic eigenfunction solution, thus completing the treatment of the problem for all values in the longitudinal variables.

From author's summary by H. Gortler, Germany

1021. Dokuchaev, N. F., The physical nature of the coefficients of heat-and mass exchange (in Russian), *Sb. Rabot. Vses. Zaochn. In-ta Pisbcb. Prom-sti* no. 3, 54–61, 1958; *Ref. Zb. Mekb.* no. 5, 1959, Rev. 5193.

Experimental data are furnished for the distribution of the temperature and concentration in the boundary layer when a sheet of water is being flown over by air. It is shown that the coefficients of heat- and mass-emission are inversely proportional to the conventional thicknesses of the corresponding boundary layers. The experimental results are given for the determined character of the relation of the coefficients of heat- and mass-emission on the velocity of the air.

A. A. Gukhman

Courtesy Referativnyi Zburnal, USSR

1022. Baron, J. R., and Scott, P. E., Some mass-transfer results with external-flow pressure gradients, *J. Aero/Space Sci.* **27**, 8, 625–626 (Readers' Forum), Aug. 1960.

1023. Lanneau, K. P., Gas-solids contacting in fluidized beds, *Trans. Inst. Chem. Engrs.* **38**, 3, 125–143, 1960.

Investigation of density gradients and transients in fluidized beds has been made with the use of very small "point density" capacitance probes. The variables studied included gas velocity and gas density. The interpretation of the experimental data has permitted the evaluation of such gas-solids contacting parameters as the distribution of solids between the dilute (bubble) and dense (emulsion) phases in the fluid bed, the relative volumes of these phases in the bed, the relative gas flow through the phases, and the gas back-mixing and interchange between the dilute and dense phases.

Based on concepts gained from these experiments, a mathematical model has been developed to describe the kinetics of first-order irreversible chemical reactions in fluid beds. The equations of the model have been numerically evaluated for different values of the gas-solids contacting parameters. The results, presented graphically, demonstrate the important influence of fluidization conditions on the efficiency and selectivity of chemical reactions in fluid beds.

From author's summary

1024. Ziemer, R. W., Instrumentation for magnetoaerodynamic heat transfer, Physical Res. Lab., Space Tech. Lab., Inc., Los Angeles 45, Calif., 35 pp., Sept. 1960.

The design, construction, and development to near completion of a heat-transfer measuring instrument are described. This work has led to the conclusion that the design principle of measuring the surface temperature of a model exposed to aerodynamic heating by means of quantitatively detecting the thermal radiation from a surface film provides a highly useful technique. Preliminary tests show that the constructed instrument will perform as anticipated and that it will respond to a heat transfer rate above 25% of the minimum obtainable in the electromagnetic shock tube.

The sole remaining problem which prevented utilization of the instrument for heat-transfer measurements in the shock tube was that of damage of the sensing film by the high-speed flow. Durable copper films were produced during the development of the apparatus but these could not be duplicated after a rebuilding of the vacuum metal evaporating unit. A series of recommendations to improve "the state of the art" of substrate cleaning and metal evaporation are given. With the solution of this final development problem, the instrument should be ready for its intended purpose, measurement of magnetoaerodynamic heat transfer.

The heat-transfer instrumentation could be used in its present state of development for the measurement of radiative heat transfer under conditions simulating the extremely high-speed atmospheric re-entry from an extraterrestrial orbit, such as from Mars.

The success of the effort up to this time should warrant continued research in the experimental study of aerodynamic heating under hypervelocity environments. One other laboratory, Langley Research Center, is now starting such a research activity. It is hoped that this report will serve to guide and encourage others who may pursue this research.

From author's summary

1025. Eckert, E. R. G., Hartnett, J. P., and Sparrow, E. M., Heat transfer bibliography, *Inter. J. Heat Mass Transfer* **1**, 2/3, 255–268, Aug. 1960.

1026. Eckert, E. R. G., Hartnett, J. P., Irvine, T. F., Jr., and Sparrow, E. M., A review of heat transfer literature 1959, *Mech. Engng.* **82**, 8, 47–61, Aug. 1960.

Combustion

(See also Revs. 930, 1000, 1039, 1041)

1027. Kovitz, A. A., and Hoglund, R. F., Laminar parallel stream mixing with dissociation and recombination, *Physics of Fluids* **3**, 3, 436–443, May/June 1960.

Authors apply the boundary-layer approximation to the mixing of two uniform (semi-infinite) parallel streams of ideal gases composed of a single atomic species plus its corresponding diatomic molecule, not necessarily initially in chemical equilibrium. The initial velocities in each stream are assumed to be uniform and equal. The chemical reaction rate is set equal to a constant times the difference between the actual local concentration and the local equilibrium concentration. The difference between the specific heats of the atoms and molecules is neglected, and the usual assumptions regarding the temperature dependence of the transport properties are made. The clearly described theoretical analysis, which leads to analytical results, is too long to discuss here. The results should be of approximate applicability for such problems as the mixing at the exit of a nozzle.

Representative concentration profiles for the mixing of partially dissociated oxygen streams are tabulated. The results show that when each stream is initially in chemical equilibrium, the concentration profiles differ little for frozen and equilibrium mixing; only for initially nonequilibrium conditions can there be a large effect. The initial departure of the concentration profiles from the frozen flow profiles is shown to be proportional to the distance downstream and inversely proportional to the product of the flow velocity and the characteristic chemical reaction time. It is also shown by expansion that when the Lewis number, Le, is near unity, the departure of the concentration profiles from their form for $Le = 1$ is proportional to $(Le - 1)$ and therefore is small.

F. A. Williams, USA

1028. Rasbash, D. J., Rogowski, Z. W., and Stark, G. W. V., Mechanisms of extinction of liquid fires with water sprays, *Combustion and Flame* **4**, 3, 223–234, Sept. 1960.

An investigation has been carried out on the extinction by means of water sprays of fires of liquids burning in a vessel 30 cm in diameter. The effect on the ease of extinction of (1) the nature of the liquid, (2) the time between the ignition of the fire and the application of the spray, (3) the properties of the sprays, and (4) the direction of application of the spray have been studied. It was found that liquids like kerosene, which can be extinguished by being cooled to the fire point, or by being diluted, like alcohol, could be extinguished reliably by certain water sprays, although in some cases the extinction took a long time. For liquids like petrol and benzole extinction depended primarily on whether or not stable flames close to the burning liquid surface were easily established following the application of spray. These stable flames were very difficult to extinguish and were usually established readily when the preburn time was very short (less than 6 to 10 seconds) and also when the spray was applied in a horizontal direction across the fire. Over the range of conditions under which extinction took place, the extinction time decreased as the rate of flow and the entrained air current in the spray increased and generally also as the drop size of the spray decreased; the effect of drop size for the petrol, benzole and alcohol fires was very marked. There was evidence that for petrol and benzole fires heat transfer between the flame and the water drops, resulting in either cooling of the flames or the formation of steam, played a part in the extinction. From authors' summary

1029. Satterfield, C. N., Kehat, E., and Mendes, Maria A. T., Burning rates and ignition temperatures of hydrogen peroxide solutions, *Combustion and Flame* **4,** 2, 99–105, June 1960.

The hydrogen peroxide decomposition flame above concentrated liquid solutions has been studied at atmospheric pressure. Mass burning rates were found to agree closely with the flame velocities as measured for the vapor by the bunsen burner method, when compared at equal adiabatic decomposition temperatures. The limiting combinations of solution concentration and temperature for ignition of flames above hydrogen peroxide solutions are reported to help establish the regions of hazard in handling this material.

From authors' summary

1030. Salooja, K. C., Studies of combustion processes leading to ignition in hydrocarbons, *Combustion and Flame* **4,** 2, 117–136, June 1960.

1031. Allen, H., Jr., and Fletcher, E. A., A study of the combustion of aluminum borohydride in a small supersonic wind tunnel, NASA TN D-296, 15 pp., July 1960.

The combustion of aluminum borohydride in the Mach 2 airstream of a 3.84- by 10-inch wind tunnel was studied by analyzing gas samples taken from the airstream. Gas mixture composition was determined with the aid of a vacuum apparatus and gas chromatograph. The over-all combustion efficiency of the fuel was assumed to be good because the combustion efficiency of its hydrogen component was found to be high. The increase of the lateral surface area of the combustion region was dependent upon the degree of mixing of fuel and its combustion products with air. In the frame zone where there was insufficient oxygen for complete combustion, the metal components of the fuel appeared to burn preferentially to the hydrogen component.

From authors' summary by W. Gumz, Germany

1032. Smith, J. M., Burning rates of solid propellants, *AIChE J.* **6,** 2, 299–304, June 1960.

A theory is developed for the burning rate of a solid propellant which is based on the assumption that the rate-governing chemical step is a reaction between a gaseous molecule A and an interfacial molecule B which is part of the solid. Differential equations are not employed. In the reviewer's opinion, heat and mass transfer between gas phase and solid and secondary combustion in the gas phase are inadequately represented in the theory. The recent theories of Rosen [*J. Chem. Phys.* **32,** 89–93, 1960; AMR **13** (1960), Rev. 4851] and Spalding [*Combustion and Flame* **IV,** 59–76, 1960; AMR **13**(1960), Rev. 5425] illustrate far more sophisticated approaches to the problem. R. Friedman, USA

1033. Zangl, W., The flow-rate coefficient as a characteristic of combustion quality in a rocket-motor (in French), *Astronaut. Acta* **5,** 2, 87–96, 1959.

Relations are developed between the mass flow in a rocket combustion chamber and the theoretically required mass flow to achieve certain operating conditions. The efficiency of combustion is deduced from the actual to theoretical mass flow ratio. In principle the method is similar to the use of critical velocity (C^*) for this purpose. Similar conclusions concerning design for high efficiency are obtained. M. Gerstein, USA

1034. Fielding, D., and Topps, J. E. C., Thermodynamic data for the calculation of gas turbine performance, Aero. Res. Counc. Lond. Rep. Mem. 3099, 115 pp., 1959.

Enthalpy, entropy, and specific heat at constant pressure are tabulated for dry air at 1°K intervals from 200 to 2000°K. To achieve accuracy of ±1.0% in specific fuel consumption without onerous computations, the method of using the difference between the property of a gas mixture and the same property for air is used. Tables for gases other than air do not give, for example, entropy directly but provide values of a function involving both air and the particular gas. Use of equations for the method is discussed. The formulas are not derived. There are many illustrative numerical examples.

The properties of any mixture of C, H, O, N, and S in the temperature range 200 to 2000°K can be computed using the tables. Dissociation is not significant and is neglected. Nonviscous one-dimensional flow with variation in specific heat can be readily determined. The entropy function which is calculated to determine pressure ratios during isentropic expansion is not the entropy for a gas mixture since it lacks entropy of mixing. The gas composition does not change so that the entropy of mixing cancels out. No statement is made concerning the restriction. Graphs of C_p, H, entropy, and constant-pressure temperature rise with fuel-air ratio as a parameter are included for a standard reference fuel. For flow calculations the total head parameter is plotted as a function of the ratio of static to total pressure.

A. Fuhs, USA

1035. Kazakevitch, F. L., Krapivin, A. M., Anofriev, G. I., and Vesely, I. G., Radiant heat exchange in a boiler furnace fired with natural gas, *Combustion* **32,** 4, 54–58, Oct. 1960.

1036. Livingston, W. L., Preventing furnace explosions, *Combustion* **32,** 3, 26–33, Sept. 1960.

1037. Dunn, J., The development of remote fuel burner control and flame protective systems, *Combustion* **32,** 3, 46–49, Sept. 1960.

Prime Movers and Propulsion Devices

(See also Revs. 1031, 1033, 1034, 1107)

Book—1038. Mayr, F., Land and marine diesel motors (The internal combustion engine, Vol. 12), 3rd ed. [Ortsfeste Dieselmotoren und Schiffsdieselmotoren (Die Verbrennungskraftmaschine, Band 12), Dritte Auflage], Wien, Springer-Verlag, 1960, viii + 471 pp. $32.55.

This is the twelfth volume of a series on internal combustion engines, edited by Prof. Hans List, Graz. This book covers the basic design, construction, and application of large diesel engines (having a bore diameter of at least seven inches).

After an introductory section on the history and materials, general considerations are presented for the design of conventional four-stroke and two-stroke diesel engines (without and with supercharging) and large diesel engines provided with crosshead. In the main part of the book, author discusses in considerable detail the calculations, permissible stresses, design, and construction of the individual engine components and accessories. This is followed by many descriptions of representative designs and constructions of large diesel engines in past and present practice in Europe, particularly in Germany. Author closes with some of the problems associated with heavy diesel fuel and examples of land and marine diesel power plants.

A wealth of information is packed into this competently written volume. Author has drawn on his long experience in the diesel engine field and stressed the practical aspects of design and application. Many formulas ready for the use of the designer are given without any derivation. Unfortunately, no bibliographical references are listed. The printing of the text and the reproduction of the numerous illustrations have been accomplished with the standards of excellence typical of books from Springer-Verlag. Reviewer believes that this book will prove indispensable to the German-reading student and design engineer working in the field of large diesel engines. F. Jindra, USA

1039. Kalitzin, N. St., and Kalitzin, G. St., A possibility for increasing the thrust of a rocket (in German), *Astronaut. Acta* **6**, 1, 75–77, 1960.

Combustion temperatures in rocket chambers are presently in the order of 3000–3500 °K. Temperature distribution across burning gas jet is not uniform, with a maximum in core region. Heating of combustion chamber walls occurs mainly through radiation and convection. If gas temperature peak can be reduced, fuels with higher calorific power can be used.

In present paper, gas jet core temperature reduction is suggested by means of injection of a cooling fluid which extracts heat from the gas through an endothermic chemical reaction. Dissociating hydrogen is considered, according to equation $H_2 = 2H - 104$ Kcal. It is essential that hydrogen be injected in a region free of oxygen to avoid combustion of coolant. Subsequent recombination into molecular hydrogen results in converse heat release with corresponding thrust increase, for which an approximate formula is given.

Process is essentially one of heat extraction at high temperature level, storage in coolant and heat release at station of decreased temperature level. No design suggestion is presented for the necessary injection apparatus, and no substantiating theoretical or experimental result is offered. This is a preliminary report. P. Schwaar, USA

1040. Campbell, C. E., and Farley, J. M., Performance of several conical convergent-divergent rocket-type exhaust nozzles, NASA TN D-467, 31 pp., Sept. 1960.

Nozzles with divergence angles α of 15°, 25°, and 29° were each tested at area ratios of approximately 10, 25, and 40 at pressure ratios up to 120. Heated air (1200° F) was supplied at the nozzle inlet at pressures up to 145 lb/sq in. abs and was exhausted into quiescent air at pressures as low as 1.2 lb/sq in. abs. Design thrust ratios varied with divergence angle according to the trend predicted by $(1 + \cos \alpha)/2$. Sizable thrust gains could be optimizing divergence angle at a given surface-area ratio (nozzle weight). A simplified method of thrust determination was developed for conical nozzles that permitted the calculation of thrust in the separated-flow region from unseparated static-pressure distributions. From authors' summary

1041. Somogyi, D., and Feiler, C. E., Liquid-phase heat-release rates of the systems hydrazine-nitric acid and unsymmetrical dimethylhydrazine-nitric acid, NASA TN D-469, 16 pp., Sept. 1960.

The initial rates of heat release were determined in a bomb calorimeter under conditions of forced mixing. The amount of mixing was varied by varying injection velocities over the range 60 to 190 feet per second. Fuel-oxidant weight ratio was also varied. Heat-release rates were found to be almost constant at injection pressures above a critical range. The rates were about 83,000 and 48,000 kcal/(sec)(mole acid) for hydrazine and unsymmetrical dimethylhydrazine, respectively. A possible combustion mechanism for these systems based on reaction at interfaces is discussed. From authors' summary

1042. Brown, H., and Nelson, J. R., Thrust orientation patterns for orbit adjustment of low thrust vehicles, *ARS J.* **30**, 7, 635–637 (Tech. Notes), July 1960.

Low thrust propulsion systems can be used for the precision adjustment of space vehicle orbit characteristics. The most effective application of these low levels of thrust requires the use of thrust orientation patterns peculiar to each type of mission. The thrust patterns most suitable for altitude correction, eccentricity reduction and Earth escape missions are identified and typical propulsion times indicated for each. From authors' summary

1043. Leo, B. S., and Hsu, S. T., A simple reaction turbine as a solar engine, *J. Solar Energy Sci. Engng.* **4**, 2, 16–20, Apr. 1960.

Theory and experimental data of a simple reaction turbine were presented by authors in "A simple reaction turbine as a solar engine," *J. Solar Energy Sci. Engng.* **2**, 3/4, 7–11, July/Oct. 1958 [AMR **12**(1959), Rev. 3063]. This article describes the design improvement and performance of the reaction turbine when operating under vacuum conditions. A method of distilling water and obtaining power simultaneously by using a closed cycle is presented. Also thermoelectric and thermionic power sources are discussed. From authors' Summary

1044. Corson, B. W., Jr., and Mercer, C. E., Static thrust of an annular nozzle with a concave central base, NASA TN D-418, 18 pp., Sept. 1960.

The annular nozzle produced a jet in which tangents to the jet streamlines at the exit converged toward a region on the axis of symmetry downstream of the exit. The internal loss was small and the thrust performance good. Pressures on the base were relatively large and positive. A predictable portion of the jet total thrust was exerted on the central base. From authors' summary

1045. Moeckel, W. E., Fast interplanetary missions with low-thrust propulsion systems, NASA TR R-79, 56 pp., 1960.

A simple family of indirect transfer trajectories between circular orbits is used to evaluate the mass ratio required to complete round-trip interplanetary missions using low-thrust propulsion systems. The results indicate that indirect interplanetary trajectories yield substantial reductions in total round-trip time for low-thrust as well as high-thrust vehicles, and that space vehicles propelled with electric rockets may produce greater reductions in trip time, for a given initial weight, than those propelled by high-thrust nuclear rockets. From author's summary

1046. Dulgeroff, C. R., Speiser, R. C., and Forrester, A. T., Experimental studies with small-scale ion motors, *ARS J.* **30**, 8, 761–763 (Tech. Notes), July 1960.

In an experimental program authors operated cesium surface ionization ion sources in ion motor configurations. Ion beam power and thrust levels per unit ionizer area up to 177 w per cm^2 and 5.6×10^{-4} lb per cm^2 have been achieved. In mass utilization

studies it was found that 70 per cent of the cesium used reached the collector as high energy ions, and over 90 per cent was ionized at the ionizer. The injection of electrons into the ion beam for neutralization purposes was accomplished by the operation of a thermionic emitter near the exit aperture of the motor, the electrons being accelerated into the beam by the ion space charge fields. From authors' summary

1047. Walker, C. L., and Matchett, J. D., A thermal energy storage system for solar powered earth satellite power plants, *GM Engng. J.* **7,** 3, 10–12, July/Aug./Sept. 1960.

An earth satellite which depends upon solar energy for the continuous operation of its power plant requires some type of system to convert solar energy to electrical energy and also to store this energy for use when the satellite passes through that portion of its orbit shaded from the sun. As part of an energy conversion research program, Allison Division research engineers have developed a proposed thermal energy storage system for an earth satellite which can be used with either a thermomechanical or thermoelectric energy conversion system. The proposed system uses the latent heat of fusion of lithium hydride as the means for storing enough energy to supply up to 45 watt-hr per lb of storage system weight. This output is somewhat greater than that currently being predicted for rechargeable storage batteries and regenerative fuel cells. From authors' summary

Magneto-Fluid-Dynamics

(See also Revs. 817, 846, 1089, 1098, 1127)

1048. Tarasov, Yu. A., On the stability of plane Poiseuille flow of a plasma of finite conductivity in a magnetic field, *Soviet Phys.–JETP* **10,** 6, 1209–1212, June 1960. (Translation of *Zh. Eksp. Teor. Fiz., USSR* **37,** 1708–1713, Dec. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

In the basic magnetohydrodynamic equation for an incompressible conducting fluid substitutions are made for the unknowns as a stationary term and a small perturbation to yield the perturbation equation.

Symmetrical solutions to the perturbation equations are sought and the final secular determinant is solved by the Tollmien graphical method.

Results are presented as graph of k against R_g for various values of the Alfvén number (appearing as closed curves). When $R_m = 1$ the critical Alfvén number is approximately 0.35 and is about 3.5 times that for ideal conductivity. A_{crit} against R_m shows very slow decrease of A_{crit} for R_m greater than 1.

Author mentions resemblance between this and classical hydrodynamic case in closure. R. S. Culver, Australia

1049. Josephson, V., and Hales, R. W., The structure of an electromagnetically driven shock, Physical Res. Lab., Space Tech. Lab., Inc., Los Angeles 45, Calif., 30 pp., Sept. 1960.

A diagnostic study of shocks produced by an electrically driven conical shock tube shows that high velocity (30–100cm/μsec) ions are accelerated out ahead of the luminous shock from by high electric fields generated by "sausage" instabilities in the conical discharge tube. Further, the high-velocity luminous front is produced by the sequential pinching of the hot ionized gas along the axis of the discharge tube, in contrast to "current loop" driven shocks in conventional T-tube discharge configurations.

From authors' summary

1050. Greenberg, O. W., Sen, H. K., and Treve, Y. M., Hydrodynamic model of diffusion effects on shock structure in a plasma, *Physics of Fluids* **3,** 3, 379–386, May/June 1960.

Using two-fluid (proton-electron) hydrodynamical model, authors investigate the structure of a steady plane shock wave in a fully ionized plasma. They assume that the dissipative effect to broaden the shock is diffusion only and that the temperatures of proton and electron are equal to each other at each point in the shock. Other dissipative effects such as viscosity are ignored, so that the continuous solution can be obtained for weak shock (Mach number < 2) only.

Two types of solution are found: one is focal in which the electric field due to the charge separation and the density oscillate in the shock (mean free path λ/Debye length λ_D being large), and the other is nodal in which the electric field has a single minimum and the density has a single overshoot through the shock (λ/λ_D being small). For the limiting case of no dissipation ($\lambda/\lambda_D \longrightarrow \infty$), there is a reversible solitary wave solution where the plasma returns to its initial state after a single oscillation of the electric field and the density. The shock width of the focal transitions is found to be proportional to λ, and that of the nodal ones is of the order of λ_D. The distance in which electric field changes occur is of the order of 10 λ_D. The peak electric field inside the shock reaches 41,700 v/cm even for weak shock of Mach number = 1.169.

S. Tomotika, Japan

1051. Pai, S. I., Shock wave propagation in an infinitely electrically conductive gas with transverse magnetic field and gravitation (in English), *ZAMM* **39,** 1/2, 40–49, Jan./Feb. 1959.

A strong shock is produced by a piston in perfectly conducting gas subject to direct gravitational and transverse magnetic fields. General Lagrangian equations and boundary conditions at piston and shock are formulated, and method of series solution followed by stepwise integration is developed. Problem is then specialized to constant vertical piston speed, magnetic field and initial temperature, and a numerical example is worked out for comparison with nonmagnetic case. Effect of magnetic field is to cause acceleration of shock.

S. Paterson, Scotland

1052. Reid, W. H., The stability of non-dissipative Couette flow in the presence of an axial magnetic field, Brown Univ., Div. Appl. Math. TR 31 (Contract Nonr 562 (07) (NR–062–179)), 7 pp., Jan. 1960.

Author determines the strength of axial magnetic field necessary to stabilize the flow of an incompressible, inviscid fluid of infinite electrical conductivity in the narrow gap between two rotating cylinders, whatever the relative angular velocities may be.

H. A. Stine, USA

1053. Killeen, J., Gibson, G., and Colgate, S. A., Boundary-layer formation in the pinch, *Physics of Fluids* **3,** 3, 387–394, May/June 1960.

Equations are set up to describe the initial behavior of deuterium gas subjected to suddenly applied parallel electric and magnetic fields. Problem is treated as one-dimensional and time-dependent in a half-plane $y > 0$ and simulates initial plasma behavior in pinch device with externally applied stabilizing magnetic field. Plane at $y = 0$ is taken to be a conductor and plasma current density $\longrightarrow$ 0 as $y \longrightarrow \infty$. Assumptions are clearly defined at each stage and are valid for short times existing prior to plasma implosion.

Final set of nonlinear partial differential equations is expressed in finite difference form and the initial-value problem solved on IBM 704 for several practical field strengths, gas densities and inductances. Scope of solutions is widened by application of simple scaling law based on pinch tube radius. Results show general "boundary-layer" behavior of plasma variables such as current density, electron and ion temperatures, etc.

J. F. Clarke, England

1054. Drazin, P. G., Stability of parallel flow in a parallel magnetic field at small magnetic Reynolds numbers, *J. Fluid Mech.* **8,** 1, 130–142, May 1960.

In this article the effects of a two-dimensional excitation of the boundary layer are studied. In conformance with earlier results it is shown that the disturbances are stabilized by a strong magnetic field when the Reynolds number is finite and the magnetic Reynolds number is small. An investigation of half and full jets provides the result that low frequency disturbances are unstable no matter how strong the magnetic field may be. Further, the magnetic field tends to increase the growth rate of inviscid long wave disturbances.

In the opinion of the reviewer this paper is of interest because it indicates the anisotropies that magnetic fields can introduce into flow problems and because it provides another example of fluid instability that is related to process that might be thought, in the absence of analysis, to be stabilizing.

E. E. Covert, USA

1055. Okada, M., Ariyasu, T., Maruo, H., and Yamada, S., Fundamental researches on plasma-jet and its application, *Technol. Rep. Osaka Univ.* **10,** 209–219, Jan. 1960.

Recently, a plasma jet device was developed in the field of high temperature production. Argon plasma jet device is used in this experiment with carbon, copper or tungsten electrodes. Current-voltage, voltage-gas flow and voltage-electrode distance characteristics are measured. It is found that the position of cathode spot has effect on the electric characteristics and on the stability of plasma jet flame. Also dark space is observed at front of anode.

Heat efficiency of 75% is obtained with high gas flow rate. Some results on plasma cutting and plasma welding are also described.

From authors' summary

1056. McCune, J. E., On the motion of thin airfoils in fluids of large but finite electrical conductivity, AFOSR TN 59-456 (Cornell Univ., School Aero. Engng.; ASTIA AD 215 030), 38 pp., Jan. 1959.

Author considers two-dimensional steady flow of an incompressible, inviscid fluid using linearized theory. Velocity and magnetic field are uniform far from the airfoil and at right angles to each other. Electric currents and vorticity are propagated away from the airfoil by Alfvén waves and the finite conductivity diffuses both. The depth of penetration of such currents into region around airfoil is found to be quite large. Whole phenomenon is very different from case with magnetic and velocity fields parallel. It is found that a perturbation solution in inverse powers of the "Magnetic Reynolds No." $= R_m = \sigma\mu lU$, where $l/\sigma\mu$ = magnetic diffusivity, l = airfoil chord, U = velocity, is successful. Behavior for $R_m \geq 5$ was essentially the same as for $R_m = \infty$. Using only the l/R_m term in the perturbation series gave good results down to $R_m = 1$.

A. E. Bryson, Jr., USA

1057. Wilcox, J. M., Boley, F. I., and De Silva, A. W., Experimental study of Alfvén-wave properties, *Physics of Fluids* **3,** 1, 15–19, Jan./Feb. 1960.

Plasma is prepared in a cylindrical tube in an axial magnetic field by discharge of a "slow" condenser bank. A radial electric field is created at one end by discharge of a "fast" bank, and the transmission of Alfvén waves, their wave velocity, attenuation, impedance and energy transfer is studied. Functional dependence of wave velocity and attenuation on axial magnetic field strength confirms theory. It is suggested that the method be used to determine plasma density and temperature. Magnetic probe measurements indicate that about 43% of the circuit energy is transferred to the hydromagnetic wave. The waveguide impedance is determined from driving current and voltage wave forms, and qualitative agreement with theory is established.

P. Savic, Canada

1058. Montgomery, D., Nonlinear Alfvén waves in a cold ionized gas, *Physics of Fluids* **2,** 6, 585–588, Nov./Dec. 1959.

Nonlinear constant-profile Alfvén waves are studied in an ionized gas in which thermal motions are negligible. The system of differential equations possesses numerous integrals, and can be solved up to a single quadrature. Many properties of the waves can be inferred without performing any numerical integrations. The waves necessarily involve nonzero magnetic field components in both directions perpendicular to the direction of propagation, and plane polarized waves are impossible except in the special case of equal mass particles. Circularly polarized modes are also a special case, and, unlike the more general solutions, involve neither longitudinal electric fields nor compression of the gas.

From author's summary by A. Kistler, USA

1059. Gajewski, R., Magnetohydrodynamic waves in wave guides, *Physics of Fluids* **2,** 6, 633–641, Nov./Dec. 1959.

Author considers periodic solutions of the linearized continuum equations of motion for a perfect gas of infinite conductivity in the presence of a uniform magnetic field. The gas has a cylindrical boundary of arbitrary cross section and the magnetic field is parallel to the cylinder axis. Solutions are produced for either a constant pressure boundary of zero conductivity or for a rigid boundary of zero or infinite conductivity. Two types of nondispersive waves are found; Alfvén waves and longitudinal acoustic waves. Also two types of dispersive waves are found, both having longitudinal and transverse components. One has a speed near the Alfvén velocity and the other a speed near the acoustic velocity.

Reviewer believes work represents a useful organization of the possible wave motions in a plasma-filled wave guide for frequencies low enough to permit neglecting the displacement current.

A. Kistler, USA

1060. Nigam, S. D., and Singh, S. N., Heat transfer by laminar flow between parallel plates under the action of transverse magnetic field, *Quart. J. Mech. Appl. Math.* **13,** 1, 85–97, Feb. 1960.

Paper considers viscous, incompressible, electrically conducting fluid moving between infinite parallel planes, with constant transverse magnetic field. Temperature of plates T_0 is constant in $x < 0$, and different constant value T_S in $x > 0$. Asymptotic solutions are given for large values of Hartmann number ($M > 10$); also simplified solutions for large Péclet number ($Pe > 100$). Results indicate that local Nusselt number increases with Hartmann number when longitudinal pressure gradient is fixed.

N. Curle, England

1061. Dazey, M. H., Josephson, V., and Wuerker, R. F., The use of low impedance transmission lines in plasma heating and confinement studies, Physical Res. Lab., Space Tech. Lab., Inc., Los Angeles 45, Calif., 29 pp., Aug. 1960.

An 18-kv type "C" transmission line of 0.28 ohms characteristic impedance, 10 μsec pulse length and 0.5 μsec rise time has been connected through a triggered air gap to a one turn copper solenoid 10 cm in diameter by 15 cm in length surrounding a cylinder of low pressure D_2 gas. Experimental measurements of the transverse pinch heating and confinement phenomena have been made via smear photographs and magnetic probes. The gas (25–500μ Hg pressure) was pre-ionized 5 μsec prior to the application of the transverse field by a 250 kc/sec linear discharge of several thousand amperes.

Application of the fast-rising constant-current transverse pinch field to the conducting plasma at 25μ pressures yields both radial implosion velocities (~10 cm/μsec) and sheath oscillatory frequencies (1–2 mc/sec) expected from theory. Diffusion of the external field into the interior of the diamagnetic plasma matches the rate of plasma loss through the ends of the confining region; e.g., at 25μ, longitudinal streaming velocities as high as 20 cm/μsec have been observed. The effect of the rate of rise of the transverse

field on the magnetic piston velocity and sheath thickness has been investigated by varying the number of transmission line sections.

From authors' summary

1062. Clauser, M. U., The magnetic induction plasma engine, Physical Res. Lab., Space Tech. Lab., Inc., Los Angeles 45, Calif., 37 pp., Aug. 1960.

A comparison of conventional electric motors and plasma propulsion engines shows that the categories of series, shunt, and induction motors are also of value when applied to the plasma engines.

The only engine which allows the plasma to be magnetically insulated from the walls, and thereby eliminates the unacceptably large heat transfer to the walls, is the magnetic induction plasma engine.

In comparing the ion engine and the plasma engine, it is seen that the ion engine is seemingly simple in concept but is proving to be complex in its design; the plasma engine, on the other hand, is complex in theory, yet like the induction motor it holds the hope of being simple in design and operation. It further appears that while the ion engine may have difficulty in achieving 1 pound of thrust, this tends to be the lower limit for the plasma engine, which can be easily extended to larger thrusts.

The use of different propellants in the MIP engine makes it possible to efficiently achieve different values of specific impulse. Deuterium is appropriate above 5000 seconds and will be used on those engines which are competitive with the ion engines. Lithium is appropriate in the 2500-3500 second range which is too low to be achieved by the ion engine and too high to be achieved by the arc jet.

Design parameters are given for a deuterium engine and a lithium engine. The calculated weights and efficiencies are encouraging.

From author's summary

Aeroelasticity

(See also Rev. 731)

1063. Movchan, A. A., Behavior of complex particular values in panel flutter problem (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **27,** 70-76, 1960.

Present paper is extension of author's previous paper titled "Stability of a panel moving in gas" which appeared in *Prikl. Mat. Mech., Akad. Nauk USSR* **21,** 2, 231-243, 1957. In that paper author confined investigations to analysis of relationship between "particular values" introduced by him as λ and reduced velocity of unperturbed motion and other parameters. "Particular value" appears under radical in expression for complex frequency. Basic results were in region of such values of reduced velocity for which "particular values" were real or had also small imaginary parts. Present paper deals with continuation of investigation to attain acceptable accuracy for panels with large damping. Author considers thin elastic rectangular panel moving in gas with hypersonic velocity and provides additional results when "particular values" of respective non-self-conjugated boundary problem becomes distinctly complex. Author's results may be employed for refining experimental finding of flutter in skins of apparatus in supersonic flight. Certain numerical sample calculations are provided. Readers will find author's previous paper helpful for familiarization with details and notations which are not repeated in this paper.

V. A. Valey, USA

1064. Crisp, J. D. C., The equation of energy balance for fluttering systems with some applications in the supersonic regime, *J. Aero/Space Sci.* **26,** 11, 703-716, 738, Nov. 1959.

The energy gradient equation for a time-varying dynamic system is developed in terms of the symmetric and skew-symmetric components of the damping and stiffness forces. General conclusions on individual effects on instantaneous stability are presented. Remainder of paper considers periodic motion, for which the energy change per cycle provides a measure of stability. In the absence of transient effects, the vanishing of the energy per cycle defines the kinematically possible conditions (necessary but not sufficient) for neutral stability. For binary systems this leads to an energy circle concept in terms of the symmetric damping coupling and skew-symmetric stiffness coupling. The vanishing of the energy circle defines a sufficient condition for ultimate stability. For higher-order systems, no such generalization is possible, although consideration of the component binaries can provide qualitative information. Applications are given in the field of supersonic flutter analysis.

The energy balance approach, while insufficient in itself, appears to be a useful auxiliary tool in stability investigation in that qualitative insight into the effects of some system parameters can be obtained with little additional effort.

H. M. Voss, USA

1065. Runyan, H. L., and Jones, Nan H., Effect of aerodynamic heating on the flutter of a rectangular wing at a Mach number of 2, NASA TN D-460, 16 pp., June 1960.

Report presents results of an experiment designed to show effects of aerodynamic heating on the flutter speed of a solid wing. Experimental results are compared to theoretical predictions. The work of Budiansky and Mayer [*J. Aero. Sci.* **23,** 12, 1081-1093, Dec. 1956; AMR **10**(1957), Rev. 2235] was used to determine the reduction in torsional stiffness. Present work assumes the wing to be long and untwisted. The test speciman had a length-to-chord ratio of 1.468 with no initial twist reported. These calculations also assume no chordwise conduction of heat. Although it is not specifically pointed out, all of these assumptions are conservative in estimating effects of aerodynamic heating on torsional stiffness.

The second-order theory of Van Dyke, NACA Rep. 1183, was used to determine the aerodynamic forces. The flutter calculations were made with a conventional Rayleigh-Ritz procedure using three degrees of freedom, first bending, second bending and first torsion.

In order to show aerodynamic heating effects within the Mach limitation of two of the wind tunnel, the air was preheated to 800°F. Instrumentation of the wing consisted of strain gages near the root to measure bending and torsion frequencies. Theoretical results showed the wing should start to flutter one second after the flow started and continue to flutter for four more seconds. The wing actually started to flutter after two seconds and fluttered for two more seconds, thus indicating the conservatism of the theoretical approach.

D. W. Breuer, USA

1066. Stepanov, R. D., Application of the method of asymptotic integration to the solution of one equation for the self-excited vibrations of shells (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **27,** 207-210, 1960.

Under certain assumptions the flutter of cylindrical shells can be solved by means of a differential equation of the type

$$Z^{VIII} + A_1 Z^{VII} + B_1 Z^{VI} + C_1 Z^{V} + (D_s + b^4 D_1) Z^{IV} + (E_2 + b^4 E_1) Z^{III} + (F_2 + b^4 F_1) Z^{II} + (G_2 + b^4 G_1) Z^{I} + (H_2 + b^4 H_1) Z = 0,$$

where $A_1, \ldots, H_2$ are functions of the independent variable. In the article its solution is carried on by asymptotic integration in the form $Z = \Theta \cdot \Phi(b \cdot \Psi)$ where Θ, Φ and Ψ are functions of the independent variable. In most cases the solution approximates fundamental beam functions.

No practical application is given.

V. Petrovsky, Czechoslovakia

Aeronautics

(See also Revs. 612, 626, 627, 647, 711, 735, 856, 878, 893, 898, 910, 1014, 1065)

1067. Theodorsen, T., Optimum path of an airplane—minimum time to climb, *J. Aero/Space Sci.* **26,** 10, 637–642, Oct. 1959.

Paper presents a straightforward analysis by variational methods of the problem of determining the flight path of an airplane for minimum time to climb to altitude. Performance parameters, including specific fuel consumption and corresponding reduction in weight, are introduced and the Euler-Lagrange equations are developed. Application is then made to the optimum climb problem with discussion of limitations imposed by physical significance of the flight parameters. Procedures are outlined for numerical calculations involving the use of digital computers. No specific numerical results are given except an indication of a 30% saving in climbing time to 50,000 ft. The basis of comparison is the time to climb to this altitude at a constant Mach number.

M. J. Thompson, USA

1068. Carstoiu, J., Minimum time-to-climb of an airplane, *J. Aero/Space Sci.* **27,** 4, p. 311 (Readers' Forum), Apr. 1960.

Note is an extension of Theodorsen's work [see preceding review] and that of the present author on the optimum time to climb to altitude for an airplane. Author shows how his earlier analysis may be employed to confirm the results obtained by Theodorsen.

M. J. Thompson, USA

1069. Trombley, E. F., The approximate solution of the equations of motion of an airplane moving in a vertical plane, *J. Aero/Space Sci.* **27,** 5, 394–396 (Readers' Forum), May 1960.

By considering the special case of climb in a vertical plane at constant Mach number, the author succeeds in reducing the equations of motion to a set of first-order differential equations. These equations are integrated numerically over a specified interval of altitude by means of a straightforward finite difference procedure. Since the Mach number and altitude are known at each end of the integration step, all aerodynamic and engine performance parameters are replaced by their average values wherever they appear in the equations. A similar procedure is used to solve the special problem of constant altitude acceleration over a specified interval of Mach number. The author gives no indication of the step-size required to obtain reasonable accuracy although he claims that the method conforms to a quick and accurate design technique. The reviewer feels that, if the range of altitude or Mach number to be covered is large, the suggested methods may become quite lenghty if high accuracy is required.

M. Epstein, USA

1070. Tipei, N., and Guta, C., On the motion of an airplane on a given trajectory (in English), *Rev. Mech. Appl.* **3,** 4, 393–403, 1958.

Paper integrates in closed form the equations of motion of an aircraft in a vertical maneuver in the incompressible flow regime and on conic section trajectories. The maneuvers are at constant thrust reduced by a term depending on the square of speed, and for the most part the aerodynamic polar is approximated by a straight line through the origin. When the latter is not suitable another simplification is available. Other simplifications are neglect of terms on an order-of-magnitude basis and the replacing of functions by sufficiently accurate and more suitable approximations. The three conventional conic section trajectories are studied. Curves of lift coefficient, load factor and speed are exhibited for a couple of elliptic trajectories. General trajectories may be treated by replacing them in segments with conic sections.

M. G. Scherberg, USA

1071. Bray, R. S., Drinkwater, F. J., III, and White, M. D., A flight study of a power-off landing technique applicable to re-entry vehicles, NASA TN D-323, 27 pp., July 1960.

Proposed technique is suitable for power-off landing of any aircraft with value of $(L/D)_{max}$ that is small (about 3 or 4), but not too small. Approach is in three phases; first is a steep glide at high airspeed in straight line aimed at point short of runway. At predetermined height second phase is started, consisting of flare at roughly constant normal acceleration. Final phase is approach in straight line, aimed at touch-down point, with small glide angle (3°) and airspeed decreasing rapidly. Conditions at end of first phase are selected to give required speed at touch-down point. Small angle of glide in third phase ensures small vertical velocity at touch-down.

Method has been tried in flight with success, using aircraft configurations having $(L/D)_{max}$ of 2.8 and 4.0.

W. A. Mair, England

1072. Swenson, B. L., A study of methods for simulating the atmosphere entry of vehicles with small-scale models, NASA TN D-90, 51 pp., Apr. 1960.

A motion and aerodynamic heating analysis of various types of lifting and nonlifting satellite entries shows that the heating-rate histories may be represented approximately by one curve if they are properly made dimensionless. A study is made of the simulation of critical thermal effects on satellite vehicles with particular attention to the use of small-scale models. The generalized heating-rate history shows that simulation of heating effects in lifting and nonlifting satellites can be accomplished with properly designed small-scale ballistic models. An atmosphere-entry simulator designed primarily for the testing of ballistic vehicles may be used to advantage for the simulation of effects in lifting and nonlifting satellites. Similarity relations are derived and an application of these relations is made to the simulation of heating effects on a lifting satellite vehicle.

R. C. Binder, USA

1073. Gessow, A., A note on the calculation of helicopter performance at high tip-speed ratios, NASA TM D-97, 13 pp., Sept. 1959.

A method of computing helicopter performance is described and illustrated that is more precise than existing procedures for conditions involving high forward speeds (tip-speed ratios above approximately 0.3). The method, which generally results in lower power requirements, uses published rotor charts and removes small-angle assumptions in regard to the magnitude and orientation of the rotor force vector and the calculation of tip-speed ratio.

L. Goland, USA

1074. Ludwig, R., Helicopter rotors with non-axial inflow (in German), Jahrbuch Wissenschaft. Gesellsch. Luftfahrt, 1957, 289–295.

Author calculates the thrust and the rotation moment given by a helicopter rotor blade, taking into consideration the angle of yaw which occurs due to the simultaneous translation and rotation motion, an effect which ordinarily is neglected in calculations. After analyzing the variation of the angle of yaw during a complete rotation of the blade, he calculates the thrust by simple relations, considering that a blade element is oriented upon the direction of the total velocity, that is upon a direction perpendicular to the vector radius passing through the instantaneous rotation center of the blade element.

Results are applied to rectangular blades and a comparison is made with ordinary calculations in which the yaw effect is not included.

V. N. Constantinescu, Roumania

1075. Payne, H. E., III, Propeller effects on the stability and control of VTOL aircraft, *Aero/Space Engng.* **19,** 3, 48–52, 64, Mar. 1960.

Paper discusses characteristics of propellers used in VTOL-STOL aircraft with primary emphasis on the effect of tilt angles up to 90°. Test data obtained from wind-tunnel experiments at the Forrestal Research Center are presented, along with analysis of the moments as affected by induced velocity. Significance of pitching as well as yawing moment is discussed.

Readability and general value of the paper is reduced by lack of a complete nomenclature and more significantly by omissions of statements as to reasons for certain steps in the analysis. The situation is further aggravated by a number of errors in equations and figures. M. J. Thompson, USA

1076. Anderson, S. B., An examination of handling qualities criteria for V/STOL aircraft, NASA TN D-331, 51 pp., July 1960.

The criteria of this report have been derived from current military requirements for helicopters and airplanes, which have been modified and supplemented by flight experience and pilots' comments from VTOL and STOL aircraft, BLC and variable stability aircraft, flight simulator and landing approach studies. It is concluded that the majority of V/STOL requirements can be defined from modified helicopter and/or airplane requirements by proper definition of reference speeds. Some areas where additional information is needed to give the requirements a firm quantitative footing are: control power and damping; dynamic stability in the transition regime; hovering steadiness; positive and negative accelerations during transition; rates of descent, flight path angles, and thrust margins in approaches. Report discusses the reasoning behind and the sources of information for the proposed requirements. H. P. Liepman, USA

Astronautics

(See also Revs. 612, 878, 907, 1045, 1048, 1071, 1072)

1077. Dommasch, D. O., and Barron, R. L., Optimum rocket trajectories: Part 1, Initial value variational solution; Part 2, Generalized boost analysis, *Aero/Space Engng.* **19,** 1, 46–50, 60, Jan. 1960; **19,** 2, 45–48, Feb. 1960.

Authors apply standard variational techniques for finding solutions to certain optimum trajectory problems. In Part I, the basic mathematical and physical processes are formulated and discussed. In Part II, the theory is extended and applied to an optimum rocket boost problem. This example assumes a spherical rotating earth. The rocket is assumed to be subjected to both lift and drag forces during the atmospheric phase of the trajectory. The results are found numerically and presented in tabular form.

R. C. Roberts, USA

1078. Graham, E. W., and Beane, B. J., Optimum trajectory problems: some special cases, Douglas Aircr. Co. Rep. SM-23687, 51 pp., Sept. 1959.

The transfer of a rocket vehicle from one point to another with minimum fuel expenditure is studied. The velocity vectors at the terminal points and the time for transfer are specified. It is assumed that the rocket vehicle is operated in a gravitational field without atmospheric resistance.

Under such circumstances the optimum procedure very often requires the use of impulses at the terminals but not at any intermediate points. In this study the emphasis is on understanding the physical situation which governs the desirability of applying intermediate impulses.

A moving coordinate system is used, and the required terminal velocity vectors are specified in this system. Also the variation of gravitational force with position produces a perturbation force field in this coordinate system.

In the examples studied two physical factors appear to be particularly important. One is the angle between the terminal velocity vectors in the moving system. The second is the angular orientation of these vectors in the perturbation force field.

Two types of analysis are considered. The first is restricted to short transfer times, but applies to arbitrary gravitational fields. The second is restricted to transfer between points on a radial line in a central force field, but the time for transfer can be large if the terminal points are properly spaced. In both methods the restrictions offer material simplifications, but each method covers some problems in which intermediate impulses are desirable and some in which terminal impulses alone are optimum. Specific examples are included as illustrations.

From authors' summary by R. C. Roberts, USA

1079. Cohen, A. D., and Rhodes, H. H., Evaluation of coasting flight of an ascending satellite vehicle for circular orbits, *ARS J.* **30,** 8, 768–769 (Tech. Notes), Aug. 1960.

The evaluation of satellite ascent paths may be facilitated by the use of parametric curves. Graphs are presented which relate conditions at the beginning of the coasting portion to those existing when the vehicle attains a horizontal attitude.

From authors' summary

1080. Kan, V. L., and Kel'zon, A. S., Stable and unstable trajectories in proportional navigation, *Soviet Phys.-Doklady* **5,** 1, 74–77, July/Aug. 1960. (Translation of *Doklady Akad. Nauk SSSR (N.S.)* **130,** 6, 1220–1223, Jan./Feb. 1960 by Amer. Inst. Phys., Inc., New York, N.Y.)

The cybernetic method of studying proportional navigation has been limited, up to the present time, to the case when the navigation constant is $b = 2$. It has been assumed, as established, that it was impossible to obtain a closed solution of even the simplest kinematic problems for $b > 2$. Locke has stated that a solution of the equations of motion can be obtained in closed form only for $b = 2$; if $b \neq 2$, numerical integration methods must be used. In engineering practice, therefore, analog computers have been applied in the solution of the problem. It is not possible, with this method, however, to obtain any over-all knowledge of the problem as a whole, or to arrive at any general conclusions that are unrelated to concrete values of the parameters and definite initial conditions of the motion. Moreover, the numerical solution of the differential equations of disturbed motion does not make it possible to draw any conclusions concerning the stability of the motion. Proportional navigation is a "complex" interdependent system, which does not permit investigation by the method of varying one factor at a time. It is just because of this that the more difficult method of analytic investigation cannot be discarded. Authors study the problem of proportional navigation for arbitrary integral values of the navigational constant. From authors' summary

1081. Munick, H., McGill, R., and Taylor, G. E., Minimization of characteristic velocity for two-impulse orbit transfer, *ARS J.* **30,** 7, 638–639 (Tech. Notes), July 1960.

Analytic solution is given to the problem treated by Lawden, that of optimum transfer from a point on an elliptical orbit to a circular orbit. More generally, the *absolute minimum* characteristic velocity path is given for transfer between two arbitrary terminals. From authors' summary

1082. Miele, A., and Cavoti, C. R., Variational approach to the re-entry of a ballistic missile, Parts I and II, Purdue Univ., School Aero. Engng. A-59-1, 55 pp., Jan. 1959; A-59-3, 59 pp., May 1959.

A simplified mathematical model describing the re-entry phase of a space vehicle is considered in which it is desired to control the drag, by means of spoilers or dive breaks, so as to minimize the heat transferred from the boundary layer to the vehicle's skin. On the mathematical side this leads to a classical problem in the calculus of variations known as Mayer's problem, the resolution of

which leads to a system of nonlinear two-point boundary-value problems. Generally speaking, even the numerical resolution of such a system is very difficult, though in the case considered one can proceed quite far analytically. Optimal programs prove to consist of subprograms in which the spoilers are fully retracted, fully extended, and continuously varied.

There is no doubt that aero-space engineers will wish to become familiar with the methods of the calculus of variations. The books by Courant-Hilbert, Bolza, Bliss, and Bellman will provide the necessary background. R. Kalaba, USA

1083. Skopinski, T. H., and Johnson, Katherine G., Determination of azimuth angle at burnout for placing a satellite over a selected earth position, NASA TN D-233, 33 pp., Sept. 1960.

Orbit characteristics and expressions are presented for relating the satellite position in the orbital plane with the projected latitude and longitude on a rotating earth surface. An expression is also presented for determining the azimuth angle at a given burnout position on the basis of a selected passage position on the earth's surface. Two illustrative examples are compared with the results obtained for an oblate rotating earth.

From authors' summary

1084. Loh, W. H. T., Minor circle flight at large angles of inclination, *J. Aero/Space Sci.* **27,** 5, 397-399 (Readers' Forum), May 1960.

A summary is given of a number of trajectory and aerodynamic heat-transfer data derived from an approximate analysis of minor circle flight of hypersonic gliders for the limiting case of large angles of inclination. The author refers the reader to other references for details of the analysis and discussions of the assumptions. Analytical formulas are presented for velocity, altitude, distance along flight path, range, deceleration, heat-transfer rates, and total heat input, all as a function of local angle of inclination. The time of flight is shown to be obtainable by direct quadrature. Comparison with exact numerical integrations shows good agreement. M. Epstein, USA

1085. Moran, J. P., The effects of plane librations on the orbital motion of a dumbbell satellite, Therm Advanced Research, Div. of Therm, Ithaca, N. Y., TAR-TN 603, 31 pp., Aug. 1960.

The equations of motion of a dumbbell satellite oscillating or tumbling in the plane of its orbit are treated by a perturbation technique which assumes the satellite's length to be small with respect to its orbital radius. The unperturbed motion is that of a point mass at the mass center of the satellite, while the equations for the perturbed motion are essentially decoupled. Analytic solutions are obtained for the particular case where the unperturbed orbit is circular. Although the perturbations induced in the orbital motion by the librational motion are usually quite small, for certain frequencies of the librations a resonance phenomenon occurs; i.e., the perturbation quantities contain secular terms, so that they grow indefinitely with increasing time.

From author's summary

1086. Tempelman, W., A graphical approach to the determination of the eccentricity and the perigee angle, *J. Aero/Space Sci.* **27,** 8, 630-631 (Readers' Forum), Aug. 1960.

A graphical method is presented for the determination of the eccentricity and perigee angle in the two-body problem for a given initial velocity and angle. From author's summary

1087. Lichtenstein, J. H., Analytical investigation of the dynamic behavior of a nonlifting manned reentry vehicle, NASA TN D-416, 55 pp., Sept. 1960.

This investigation encompassed the effects of aerodynamic derivatives and spin rate, reentry angle and velocity, geostrophic winds, and a drogue-parachute stabilizer on the vehicle as it descended through the atmosphere. It was found that considerable damping was necessary in the low-speed portion of the flight and that this damping could be enhanced by employing a drogue parachute. Neither the reentry angle, renntry velocity, nor the geostrophic winds had a serious effect on the stability although they did have an appreciable effect on the range of the vehicle. Small amounts of spin did not seriously affect the stability but high spin rates had a deleterious effect. From author's summary

1088. Chang, H. H. C., and Smith, M. C., On the drag of a spherical satellite moving in a partially ionized atmosphere, *J. Brit. Interplanetary Soc.* **17,** 7, 199-205, Jan./Feb. 1960.

Authors investigate theoretically the subject problem for an earth atmosphere consisting of electrons, oxygen and nitrogen atoms and ions, where the ions and electrons are approximately at the same thermal temperature. Under these assumptions, the satellite travels at a subsonic velocity compared with that of the electrons and at supersonic velocity compared with the moving ions. Thus the satellite appears to be bombarded from all directions by electrons while the ions are swept out along its path. The result is a negative charge on the satellite. Authors determine first the satellite's effective area for colliding ions and electrons. Then they calculate the satellite potential, the Coulomb drag resulting from collisions, the dynamic friction and the influence of an electric field sheath surrounding the satellite. An estimate of the photoelectric effects from the radiation of the sun is given. K. Pohlhausen, USA

1089. Kraus, L., and Yoshihara, H., Electrogasdynamic motion of a charged body in plasma, *J. Aero/Space Sci.* **27,** 3, 229-233, Mar. 1960.

The premises for treating plasma as a fluid to which hydrodynamic considerations may be applied have been stated and discussed. The basic equations governing the motion of plasma, assumed to be composed of electrons and singly ionized atoms of one chemical species, are set up and the equations for perturbations to undisturbed free-stream plasma are derived. The two possibilities when the free-stream velocity is less than or greater than the ion sound speed are briefly discussed. The perturbation equations are further simplified by assuming that the Debye radius is very small in comparison with other lengths of interest and the flow of plasma over a thin two-dimensional dielectric body is discussed. The total drag experienced by the body is found as the sum of the pressure drag and the electrostatic drag. The paper is primarily concerned with the motion of a body through plasma where electrostatic phenomena are significant.

S. D. Nigam, India

1090. LaGow, H. E., and Alexander, W. M., Recent direct measurements by satellites of cosmic dust in the vicinity of the earth, NASA TN D-488, 11 pp., Sept. 1960.

Direct measurements of the space density of cosmic dust particles in the vicinity of the earth have been made from rockets, satellites, and space probes. The largest data samples have been obtained from crystal transducer sensors that detect the impact impulses occurring from the collision of dust particles on sensitive surfaces of space vehicles. Preliminary results from satellite 1959 Eta show: (1) over 1500 impacts and an area-time product greater than 10^{10} cm^2-sec, and (2) a daily variation in the dust particle density near the earth. The dust particle instrumentation of 1959 Eta and sensor calibration techniques are discussed in this paper. The results of direct measurements from space vehicles prior to 1959 Eta are summarized with respect to 1959 Eta information. From authors' summary

1091. Reiffel, L., Structural effects and particle content of interplanetary space, *ARS J.* **30,** 7, 654-655 (Tech. Notes), July 1960.

Calculations on structural damage by solar plasmas are presented which show that solar helium is the dominant influence in sputtering, whereas solar hydrogen dominates radiation damage effects. Newly available laboratory data are used to calculate erosion rates in space. From author's summary

1092. Harry, D. P., III, and Friedlander, A. L., Exploratory statistical analysis of planet approach phase guidance schemes using range, range-rate, and angular-rate measurements, NASA TN D-268, 81 pp., Mar. 1960.

An exploratory analysis of schemes applicable to the guidance and control of the approach to a target planet is presented including digital solutions of statistical probability. Control logic is evaluated on the basis of guidance accuracy and velocity-increment requirements for trajectory correction.... The instrumentation system is assumed to produce simultaneous range, range-rate, and angular-rate $\dot{\theta}$ measurements.... It is assumed the dominant source of error is in the $\dot{\theta}$ measurements. A system of measurement based on radar or radio techniques in conjunction with gyroscopic determination of an inertial reference direction is accurately approximated.... Results indicate that guidance logic is relatively insensitive to mission energy or to residual errors from midcourse guidance.... The guidance scheme is, however, sensitive to the altitude of the target perigee.... A large range of $\dot{\theta}$ measurement errors is considered, and use of the radar-gyroscopic system is considered feasible for guidance to atmospheric-drag deceleration accuracies with instrument of current performance expectations.

A strong trend toward heavily "restrained" and "damped" guidance system is indicated, and a large number of corrections in trajectory following initiation of guidance at long range would be desired. It is indicated that active control with no cutoff is preferred. Control engines require a range of velocity increments of 50/1 for good control performance, with a minimum acceleration capability of 1/3 g, or 1 g for drag deceleration approaches.

From authors' summary by T. Hacker, Roumania

1093. Wong, T. J., and Slye, R. E., The effect of lift on entry corridor depth and guidance requirements for the return lunar flight, NASA TR R-80, 38 pp., 1960.

Corridors for manned vehicles are defined consistent with requirements for avoiding radiation exposure and for limiting values of peak deceleration. Use of lift increases the depth of the entry corridor. Mid-course guidance requirements appear to be critical only for the flight-path angle. Increasing the energy of the transfer orbit increases the required guidance accuracy for the flight-path angle.

Corrective thrust applied essentially parallel to the local horizontal produces the maximum change in perigee altitude for a given increment of velocity. Energy required to effect a given change in perigee altitude varies inversely with range measured from the center of the earth. From authors' summary

Ballistics, Explosions

(See also Revs. 586, 754, 948, 967)

Book—1094. Zeldovich, Ia. B., and Kompaneets, A. S., Theory of detonation (Translated from the Russian, 1955 ed.), New York, Academic Press, Inc., 1960, 284 pp. 10.

This monograph is a systematic presentation of the work on the theory of detonation of the Chemical Physics Institute of the Academy of Sciences of the USSR up to 1955. Although much has been done since that time, as can be seen by consulting the Proceedings of the last two Symposia on Combustion, the book is still a useful summary of the basic theory.

The first chapter is a review of gasdynamics, particularly shock waves. The second and third chapters treat detonation in gases without and with heat transfer and frictional losses. These chapters are essentially a filling in of the details of the discussion of detonation in Zeldovich's 1944 monograph. The fourth chapter is a brief account of detonation in solid and liquid explosions, and the last chapter deals with some gasdynamical problems involving the motion of the detonation products.

The exposition is very clear and the translation good except for rare slips, such as the use of impedance for resistance in the fluid mechanical sense. The principal limitation of the book is the concentration on the work of a single school. A more comprehensive survey of the field, which the authors are well qualified to give, would be of great value. Also, the treatment of experimental techniques is weak. Reviewer would recommend M. A. Cook's "Science of high explosives" [Reinhold, New York, 1958] as a useful complement.

The price of the book seems high. There is no index. While the print is legible, the typographical device of skipping a line between paragraphs wastes the equivalent of at least ten pages. Reviewer believes that it would have been very useful to the reader if the availability of translations of Russian references had been indicated. W. Squire, USA

1095. Kompaneets, A. S., A point explosion in an inhomogeneous atmosphere, *Soviet Phys.-Doklady* **5,** 1, 46-48, July/Aug. 1960. (Translation of *Doklady Akad. Nauk SSSR (N.S.)* **130,** 5, 1001-1003, Jan./Feb. 1960 by Amer. Inst. Phys., Inc., New York, N.Y.)

1096. Wolfhard, H. G., and Bruszak, A. E., The passage of explosions through narrow cylindrical channels, *Combustion and Flame* **4,** 2, 149-159, June 1960.

The transmission of explosions through narrow channels is investigated in this paper. The channels connect two explosion chambers. Ignition in the outer chamber following firing of an explosive mixture in the inner chamber depends on the geometry of the channel. It has been found that a propagating methane-air flame does not travel through channels of less than about 3-mm diameter, although ignition may still occur in the outer chamber. The hot burnt gases from the inner chamber issue into the outer chamber and may lead to ignition which originates in the hot eddies of the turbulent jet. Ignition or non-ignition depends mainly on the gas dynamic properties of the jet, which in turn depend on the channel geometry. This mode of ignition is confirmed by theoretical considerations, as well as by the nature of the experimental results showing, for example, that very short channels are more efficient in preventing outside ignition than channels of about 10-mm length. Schlieren pictures of the outside ignition process also confirm the proposed mechanism.

From authors' summary

1097. Boyer, D. W., Spherical explosions and implosions, Univ. Toronto, Inst. Aerophys. Rep. no. 58, 116 pp., Nov. 1959.

Paper deals with an experimental investigation of the explosions of 2-inch diameter glass sphere under high internal pressure (400 psi helium and 326 psi air). Experiments on the simulation of high-altitude explosion are also reported. The experimental wave phenomenon (observed by schlieren and spark-shadowgraph records) shows good quantitative agreement with the theoretical predictions. In an appendix an account is given of some initial experiments on the implosion of glass spheres.

C. Franze, Germany

1098. Basu, S., Ionization in seeded detonation waves, *Physics of Fluids* **3,** 3, 456-463, May/June 1960.

This paper reports an investigation of equimolal oxyacetylene detonations at 1/10-atm initial pressure, which were seeded with

potassium acetylide (C_2HK) to obtain good electrical conductivity. Finely ground (10-μ mean diam) potassium acetylide was injected into the initial mixture and the density of the resulting aerosol was determined by a sedimentation technique. The electrical conductivity was determined by a magnetohydrodynamic interaction method developed by Lin. The measured conductivities were compared with the results of thermodynamic equilibrium calculations, which included the cooling effect due to the heat capacity of the additive. Predicted and measured conductivities have approximately the same dependence on the mole fraction of potassium which was varied from 0.1 to 10%. At the temperatures of interest (3500–4000°K), reported values of electron-gas (CO, H, and H_2) and electron-potassium collision cross sections are about 10^{-15} cm^2 and 40×10^{-15} cm^2, respectively. With these values, the theoretical and measured electrical conductivities agreed within a factor of two, the agreement improving with increasing mole fraction of potassium. An electron-gas cross section of 2.5×10^{-15} cm^2 gave good agreement between theory and experiment. The maximum measured conductivity was 2.7 mho/cm and occurred at about 3% potassium in the product gases. Ionization was essentially complete within about 40 μsec behind the wave front.

From author's summary

1099. Filler, W. S., Measurements on the blast wave in a conical tube, *Physics of Fluids* **3,** 3, 444–448, May/June 1960.

Spherical high-explosive blast waves were studied under simplified laboratory conditions using a sector shock tube and detonating at its apex a high explosive. In the experiment, a quantity of explosive equivalent in energy to ½ g of TNT was used. Pressure-time histories of the shock waves produced in the cone were obtained with piezoelectric gages. These waves were shown to possess the typical features of spherically expanding blast waves. The magnitudes of the peak pressures, positive durations, and impulses of the shock waves were found to be characteristic of those produced by spherical charges of about 60 times the weight of explosive actually used. This falls short of the design amplification of the 22-deg cone used by about 40%. However, amplification effects larger by several orders of magnitude appear possible with the use of cones having smaller angles.

From author's summary

Acoustics

(See also Revs. 847, 861, 911, 918, 939, 966)

1100. Tolstoy, I., and May, J., A numerical solution for the problem of long-range sound propagation in continuously stratified media, with applications to the deep ocean, *J. Acoust. Soc. Amer.* **32,** 6, 655–660, June 1960.

Author's work concerns a numerical method applied to the analysis of the far field acoustical pressure due to a simple harmonic point source. The problem is restricted to low-frequency propagation. The method assumes the medium is composed of layers in each of which the sound velocity $\alpha_i(z)$ varies continuously as $(p_i z + q_i)^{-\frac{1}{2}}$, where z is the coordinate in the thickness direction of the layer. The wave functions for a layer are then known (combinations of Bessel functions of order $\pm 1/3$). These functions are then represented by polynomials or by the leading terms of their asymptotic expansions. Solutions follow with the aid of a computer (moderately fast). The method (an eigenfunction approach) is particularly suitable where the ray theory method breaks down. Results and limitations of the method are discussed.

J. Miklowitz, USA

1101. Brigham, G. A., and Borg, M. F., An approximate solution to the acoustic radiation of a finite cylinder, *J. Acoust. Soc. Amer.* **32,** 8, 971–981, Aug. 1960.

Utilizing the assumption of an omni-directional point source and varying degrees of acoustical transparency associated with a finite cylindrical shell with rigid end caps, the authors have derived two separate approaches to the problem of far-field sound radiation emanating from a normal mode of vibration. In addition, a third approach is obtained by expanding the expressions of Laird and Cohen and applying them to a shell-band source on an infinite cylinder. Several different environments are considered for each approach and for one of these environments, the results are compared to the experiment.

The comparison of these theories indicates that for acoustic wavelengths considerably greater than structural wavelengths and dimensions, the assumption of omni-directional point sources and acoustical transparency is reasonable even though the source is curved and "unbaffled." At higher frequencies, the pressure levels and directivity in the far field are approximately independent of the transparency or opaqueness of the source, thus indicating that an "equivalent" transparent cylinder of infinitesimal spherical sources could give, at most, only three- or four-db cancellation effects when a single mode excitation basis is assumed.

From authors' summary

1102. Naugol'nukh, K. A., and Romanenko, E. V., Amplification factor of a focusing system as a function of sound intensity, *Soviet Phys.-Acoustics* **5,** 2, 191–195, Nov. 1959. (Translation of Akust. *Zh., USSR* **5,** 2, 191–195, Apr./June 1959 by Amer. Inst. Phys., New York, N. Y.)

The diminution in the amplification factor of focusing systems and radiators due to nonlinear wave form distortions is investigated. A parametric expression is obtained, permitting an evaluation of a focusing system from the point of view of the influence of the nonlinear effects on its amplication factor.

An experimental verification of the results obtained is made. Using miniature pickups, the wave form near the focus and the amplification factors of three focusing radiators of the barium titanate ceramic type were investigated. Pulse techniques are applied, with the operating frequency of the radiators at 0.5, 1.4, and 2.2 Mc. The maximum amplitude of the pressure at the focus of the radiator was about 200 atmos ± 20%. With the application of pulsing (a continuous impulse of 100 μsec, and a frequency of 1.4 Mc), and at this pressure cavitation set in.

J. S. Arnold, USA

1103. Payton, R. G., Transient interaction of an acoustic wave with a circular cylindrical elastic shell, *J. Acoust. Soc. Amer.* **32,** 6, 722–729, June 1960.

Author considers the transient interaction of an infinitely long circular elastic shell, surrounded by an acoustic fluid, with a plane pressure pulse whose front is parallel to the axis of the shell. Author uses Friedlander's technique of replacing the shell by a fictitious Riemann surface. By the use of integral transform techniques, exact expressions are then found for the subsequent motions of the shell and the fluid in the form of double integrals. Author uses the method of steepest descent to obtain asymptotic solutions for the early time motion of the shell and fluid. It is shown that during the early motion, the radial velocity of the shell and the bending moment have a maximum, while the fluid pressure at the interface experiences a minimum.

T. K. Caughey, USA

1104. Igarashi, J., and Toyama, M., Fundamentals of acoustical silencers, Part 1, Theory and experiment of acoustic low-pass filters, Aero. Res. Inst., Tokyo University Rep. 339, 223–241, Dec. 1957.

Attenuation characteristics of several acoustical low-pass filters have been studied theoretically and experimentally. A method of electrical equivalent network was applied to the acoustical elements, such as cavities, resonators, internal tube-type cavities

and cavities with absorbing material. Each element was represented by a four-terminal matrix, and attenuation of the system was calculated from their products.

By an automatic recording system, frequency characteristics of various acoustical elements and their combination were measured. They show good agreement with calculation.

Reviewer believes that although the results obtained may be found elsewhere [e.g. Harris, "Handbook of noise control," McGraw-Hill] the presentation is very clear and concise, and that the paper is a useful reference. J. M. Bowsher, England

1105. Miwa, T., and Igarashi, J., Fundamentals of acoustical silencers, Part 2, Aero. Res. Inst., Tokyo University Rep. 344, 67–85, May 1959.

This paper is a continuation of Part I [see preceding review] and is devoted to the determination of the four terminal constants of the fundamental elements of acoustic filters. The experimental method and some results are reported. They are in general agreement with the theory. Attenuation of a combination filter was also calculated from measured terminal constants. Corrections for elements of size large compared with the wavelength are considered. This paper is somewhat more mathematical in content than Part I.

J. M. Bowsher, England

1106. Powell, A., Aerodynamic noise and the plane boundary, *J. Acoust. Soc. Amer.* **32,** 8, 982–990, Aug. 1960.

In an earlier paper entitled "Thoughts on boundary layer noise" [Aeronautical Research Council Report 16727, 1954], it was pointed out that while the fluctuating pressures exerted upon a rigid boundary by a contiguous unsteady flow can be shown in a formal manner to generate sound as of a distribution of dipoles, it can be argued by means of the reflection principle that all such dipole effects cancel out in the case of the boundary being plane; yet observations of aeolian tones adequately confirm the presence of effective dipole-like generators in that case. Here the image principle is developed in a rigorous manner and the apparent paradox is resolved with the help of an extension of Lighthill's and Curle's analyses to include boundaries which are not wholly immersed in the noise-generating flow. In particular, it is shown that the pressures exerted on a plane boundary are simply reflections of the quadrupole power, in fact a quadrupling when the wavelength is relatively large, except that degeneration into octupoles occurs for those lateral quadrupoles of the type that would be associated with fluctuations across the shear of an adjacent boundary layer. Under these circumstances it should be possible to estimate the noise of a plane turbulent boundary layer with satisfactory accuracy from sufficient knowledge of the principal quadrupole source strength alone (provided that it is reasonable to neglect the contribution of the fluctuating shear stresses acting on the boundary).

From author's summary

1107. Sutherland, L. C., and Morgan, W. V., Use of model jets for studying acoustic fields near jet and rocket engines, *Noise Control* **6,** 3, 6–12, May/June 1960.

1108. Westley, R., Aerodynamic sound and pressure fluctuations in a supersonic blowdown wind tunnel, Nat. Res. Counc., Canada, LR-274, 54 pp., Jan. 1960.

An investigation was made of the pressure fluctuations in the settling chamber and working section and of the exterior sound fields of the N.A.E. 5-inch supersonic blowdown wind tunnel. Intense pressure fluctuations found in the settling chamber of the wind tunnel were a function of the flow conditions at the control valve, which suggested that they were aerodynamic noise originating from the jet of the control valve.

Below a working section Mach number of 3, the fluctuations in the working section were found to be predominantly those which had been transmitted from the settling chamber. The attenuation of the transmission increased with increase of working section Mach number and at Mach numbers greater than 3 the working section fluctuations became almost independent of the fluctuations in the settling chamber.

The sound field surrounding the wind tunnel and the sound pressure levels at the exit of the exhaust diffuser were also measured.

From author's summary

1109. Hamme, R. N., Understanding sound transmission loss of lightweight partitions, *Noise Control* **6,** 3, 13–17, May/June 1960.

1110. Freeman, J. J., A systematic error in underwater acoustic direction-finding, *J. Acoust. Soc. Amer.* **32,** 8, 1025–1027, Aug. 1960.

Postulating a uniform volume distribution of noise sources as a model of ambient ocean noise, the effect of the coherence between noise measured at different locations is examined. The systematic error introduced by this coherence in cross-correlator direction-finding systems is evaluated. Also, the relation of the maximum useful averaging time to the degree of coherence is derived.

From author's summary

1111. Wilson, W. D., and Taylor, D. D., Sound velocity measurement in liquids, *Electronics* **33,** 37, 69–71, Sept. 1960.

Instrument for direct measurement of velocity of sound in sea water has many possible industrial applications—it will detect impurities to one part in 100,000 by weight when impurity is in solution.

From authors' summary

1112. Lomask, M., and Frassetto, R., Acoustic measurements in deep water using the Bathyscaph, *J. Acoust. Soc. Amer.* **32,** 8, 1028–1033, Aug. 1960.

The Bathyscaph *Trieste* made a series of dives for scientific purposes in the summer of 1957 in the Mediterranean Sea. Part of the work consisted of simple acoustic measurements in the 10- to 500-cps frequency range, and is herein described. Ambient noise levels were measured with some detail as a function of depth, sea state, and frequency; and pressure levels from a surface source were measured as a function of depth at different ranges, one range before the energy concentrated in the sound channel, and one range afterwards. Finally, the capabilities and limitations of the Bathyscaph as a vehicle for acoustic experiments are discussed.

From authors' summary

1113. Lane, R. N., and Mikeska, E. E., Field measurement of sound transmission loss, *Noise Control* **6,** 3, 18–22, May/June 1960.

Micromeritics

(See also Revs. 818, 825, 844, 917, 984)

Book—1114. Batel, W., Introduction to the technique of grain-size measurement; Grain-size analysis, characterization of granular goods, determination of surface area, sampling [Korngrossenmesstechnik; Korngrossenanalyse, Kennzeichnung von Kornungen, Oberflachenbestimmung, Probenahme], Berlin, Springer-Verlag, 1960, viii + 156 pp. DM 27.

In the technology of granular goods and milled products, as in mining, ore preparation, ceramic industries, chemical and food industries, the knowledge of grain structure is of basic importance; even more so in the technology of dusts, especially in dust removal. Extensive research work has been devoted to clearing up the multitudinous problems in this field. The purpose of this book is to present the body of knowledge in this field in a systematic manner, in order to facilitate its understanding and use. It

treats the technical and statistical problems of sampling of aerosols, suspensions, and bulk goods; the reduction of the sample to the quantity to be analyzed; the measurement of grain size and their frequency; and the various methods of grain-size representation. Furthermore, experimental methods for determining significant characteristic quantities, such as the surface area, are described.

Titles and contents of chapters: Graphical representation and characterization of grain-size distributions (normal, logarithmico-normal, Rosin-Rammler-Sperling distributions; 23 p., 13 fig., 22 ref.); Sampling (definitions, sampling of bulk products, of suspensions, of aerosols, division of samples; 24 p., 23 fig., 27 ref.); Grain-size analysis (test sieving, sieves, tolerances of mesh width, etc.; separation by falling velocity, general relationships, sedimentation in gas and in liquid, in gravity field and in centrifugal field; microscopic grain-size analyses by light microscope and by electron microscope; comparison of various methods of analysis; 75 p., 55 fig., 55 ref.); Methods of direct measurement for surface area and other characteristic quantities (gas adsorption, absorption of solutes, wetting methods, permeability methods, optical and other methods; 16 p., 9 fig., 24 ref.); Some examples for the application of grain-size analysis (7 p., 9 fig., 3 ref.).

The treatment is authoritative, clear, and complete; literature in German and English is covered up to about 1958; the illustrations and numerical examples are well chosen and explained. The book should be of great help to those concerned with some aspects of particulates, and can be regarded as a valuable addition to existing literature on dust, powder, and other dispersions.

K. J. DeJuhasz, USA

1115. Muschelknautz, E., Theoretical and experimental investigations on the pressure loss in pneumatic conveyors with special regard to the influence of friction and weight of materials to be conveyed (in German), *VDI Forschungsheft* **25**, 476, 32 pp., 1959.

Paper opens with an effective one-dimensional analysis of the mechanics of steady-state pneumatic transport, taking into account gravity forces, solid friction between the particles and the duct walls, and fluid drag of the gas flow on the particles. The drag is taken as fully turbulent. Consideration of the impact and rebound of particles from the duct walls leads to the derivation of a wall friction coefficient, and this is incorporated in an over-all duct friction factor for the supplementary pressure loss due to solid transport. This supplementary loss is taken as purely additive to the duct friction for the gas flow alone. Analysis so far is valid only for small to moderate concentrations of coarse particles (with terminal velocities exceeding 9 fps), assuming uniform distribution of particles in conveying gas and no interaction between particles.

Next, analysis is extended to take into account the additional forces arising from collisions between large slow-moving particles and small fast-moving particles. A subsidiary experimental investigation of the vertical transport of a mixture of two particle sizes shows that the complexity of the extended analysis can usually be avoided by the use of averaged particle properties, at least for larger concentrations of solids.

The principal experimental section gives detailed observations of forces and velocities involved in the impact of granular solids on rotating metal disks. Friction coefficients are deduced for a number of particle and surface materials used in conveying practice. Finally, a wide range of published and unpublished measurements on the horizontal conveying of wheat, mine tailings, quartz, carborundum and glass-spheres is examined in the light of the foregoing. Friction factor and particle/gas velocity ratio are expressed in terms of Froude numbers based on gas and particle terminal velocities respectively. In general, two regimes can be distinguished; at large gas velocities, wall friction predominates and friction factor is fairly constant; at low gas velocities, gravity effects predominate and friction factor rises steeply (being defined as inversely proportional to gas velocity squared).

Correlation of theory and observations is on the whole satisfactory. Reviewer believes paper to be a valuable contribution, especially in view of analysis of particle interaction and presentation of new results on wall friction and on conveying. Further work on particle interaction and on scale effects in still needed, however.

J. A. Cole, Australia

1116. Platonov, P. N., The pressure of a granular medium when changing over from boundary equilibrium to a state of motion (in Russian), *Izv. Vyssh. Uchebn. Zavedenii. Pishch. Tekhnol.* no. 1, 92-96, 1958; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 3085.

This is a description of an experimental investigation on the determination of the pressure of a granular medium (steel balls 8 mm in diameter, sand, wheat) falling with a constant velocity on a platform in a cylindrical vessel. The area of this platform is from 57 to 9 times smaller than the bottom of the vessel. Data are given to illustrate the change of pressure on the platform in relation to the absolute magnitude of its movement which show that at the beginning the pressure falls sharply, then subsequently approaches a certain measure of constancy for the given conditions of the magnitude. The pressure depends on the location of the platform at the bottom of the vessel and on the dimensions of this platform relative to the bottom of the vessel.

M. V. Malyshev

Courtesy Referativnyi Zhurnal, USSR

1117. Kazakevich, F. P., and Krapivin, A. M., Investigation of heat transfer and of the aerodynamical resistance in tube assemblies when the flow of gas is dust-laden (in Russian), *Izv. Vyssh. Uchebn. Zavedenii. Energetika* no. 1, 101-107, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5204.

Results of the investigation given in the title are published. This was carried out in plant which was a built-on unit to a boiler-utilizator; the plant is described in detail; the procedure employed in the experiment is also detailed. The results are presented in the form of curves showing the criterial relation of $N = f(R)$. Convergence of the relations obtained with the well-known formulas evolved by Mikheev and the VTITsKTI is determined. A note is made of the fact that contamination is accompanied by decreases in heat emission and aerodynamical resistance. The influence of the emission of the dust-laden medium is evaluated in a very clumsy fashion.

A. A. Gukhman

Courtesy Referativnyi Zhurnal, USSR

Book—1118. Fuks, N. A., The mechanics of aerosols (in Russian), Moscow, Izd-vo Akad. Nauk SSSR, 1955, 352 pp. + illus. 19 r.; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 2794.

The book is a collection of critically analyzed results of theoretical and experimental investigations on the motion of aerosol particles, their settlement and coagulation and also on the phenomena taking place when the particles make contact with each other and with microscopic bodies. A brief examination is carried out of the basic properties and statical characteristics of aerodispersion systems. Data are expounded in detail regarding the resistance of the medium to the motion of spherical and ellipsoidal particles in the case of an even rectilinear motion and when under the action of a constant force (for instance, of the force of gravity, of an electric field and of radiometric forces). The uneven motion of aerosol particles is much more complex and varied than the motion at a constant velocity. The principles of the uneven rectilinear motion can be quite adequately studied at small Reynolds numbers. With large Reynolds number there are only the corresponding experimental data and these are scanty and contradictory.

An important example of uneven rectilinear motion of aerosol particles is furnished by the vibration of particles under the action of sound waves. The hydrodynamic attraction of the particles in the sonic field is a matter of interest in connection with the phenomenon of ultrasonic coagulation. The action of sound waves on

the suspended particles is not limited by forces varying with direction; a "sonic pressure" also acts on the particles, this being dependent on the density of the medium. Together with the question of the action of sonic waves on aerosol particles the facts regarding the dissipation and absorption of sound waves by aerosols are briefly stated. The theory regarding the curvolinear motion of aerosol particles is comparatively simple at small R numbers, but becomes fundamental for the solution of problems on the settlement of aerosols from a laminar flow under the action of the forces of gravity, an electric field, a centrifugal force, and also for the problems dealing with the settlement of aerosol particles on various bodies being flown about by a current.

A matter of large practical interest is the question of the diffusional settlement of aerosols on the surfaces of solid and fluid bodies (such as, for instance, the settlement of aerosols on filters). Formulas characterizing the diffusional settlement of aerosols in an immovable medium are only applicable in cases where the volumes of gas concerned are comparatively small. The more difficult problem on the diffusional settlement of aerosols from a laminar flow of gas has been solved only for a very limited number of cases. However an undisturbed laminar flow is met with comparatively rarely because of the presence of convection. The principles of the settlement of aerosols with convection and turbulence diffusion in operation form the basis of investigations regarding the propagation and settlement of atmospheric aerosols. A detailed examination is made of the various forms of aerosol coagulation; the thermal (Brownian) coagulation of monodispersion and polydispersion aerosols with spherical particles and particles of elongated form; the heat coagulation of aerosols with charged particles; coagulation in an electrical field; coagulation under the action of sonic vibrations; kinematic (gravitational) coagulation, coagulation during mixing and coagulation in a turbulent flow.

A question closely allied with the problems of aerosol mechanics is the break-away of the particles from walls and of the transformation of bodies in powder form to the aerosol state. The theoretical and experimental study of this question is still in the early preliminary stage. S. V. Pshenai-Severin

Courtesy Referativnyi Zhurnal, USSR

1119. Soo, S. L., Effect of transport processes on attenuation and dispersion in aerosols, *J. Acoust. Soc. Amer.* **32,** 8, 943-946, Aug. 1960.

Dispersion and attenuation of sound waves (sonics and ultrasonics) in aerosols were studied. Effects of momentum and heat transfer between the solid particles and the gas were considered. Significance of relative acceleration of particles is demonstrated.

From author's summary

1120. Wadsworth, J., Experimental examination of local processes in packed beds of homogeneous spheres: Part 1, The local packing in randomly stacked sphere beds; Part 2, The local heat transfer over the surface area of a sphere immersed in a packed bed of infinite dimensions and arranged in rhombohedral array, Nat. Res. Counc., Canada, MT-41, 69 pp., Feb. 1960.

Part I. The local packing, occurring in cylindrical containers when randomly stacked with homogeneous spheres, is examined over a range of 4 to 24 of the ratio of container diameter to sphere diameter. Sphere packings are examined both as a function of radial and vertical position in the bed. It is concluded that only one kind of close packing exists or tends to exist in random packing, i.e. rhombohedral. Some understanding of the packing mechanism has evolved for the largest cylindrical container, i.e. container-to-sphere-diameter ratio of 24.

Part II. A three-dimensional picture is presented of the heat transfer over the surface area of a sphere when immersed in a packed bed of "infinite" dimensions arranged in rhombohedral no. 6 blocked passage array for a range of Reynolds numbers of 8,000 to 60,000, where Re number is based on sphere diameter, average velocity of the coolant across the cross section of the bed in the absence of the spheres, and fluid properties evaluated at the mean film conditions.

From author's summary

1121. Murdoch, R., and Kearsey, H. A., Pumping studies on aqueous thoria slurries, *Trans. Inst. Chem. Engrs.* **38,** 3, 165-175, 1960.

Pressure drop-flowrate measurements have been obtained for various aqueous thoria slurries in a vertical pipe-line viscometer at 25°C to investigate the effect of concentration, pumping, and method of preparation. These slurries are generally non-Newtonian, and it was found that their rheological properties could be correlated by means of the Crowley-Kitzes equation over a wide range of conditions. The single constant, C, for a slurry of a particular material enables flow data to be predicted for any concentration of that material. Its value was found to be a maximum for fully flocculated slurries and a minimum for deflocculated ones. For flocculated slurries its value increased as particle size decreased.

The viscometer results have been compared with some obtained in a pumped loop using larger diameter pipes. The velocity of transition from laminar to turbulent flow is reasonably predicted for vertical pipes by the point of intersection of the laminar flow curve calculated from the viscometer results with the turbulent friction factor curve for the appropriate concentration of slurry. The latter curves were not influenced by pipe diameter or the value of C, but were influenced by concentration. In horizontal pipes inhomogeneity occurs at velocities between approximately 1.5 and 3.0 times the predicted transition velocity.

From authors' summary

1122. Novak, P., Study of the performance and efficiency of bed-load meters (in Czech), Výzkumný Ústav Vodohospodárský, Práce a Studie, Praha no. 99, 89 pp., 1959.

A valuable survey of bedload samplers used in 10 different countries, with description of 24 specimens. Author compared several of them and evaluates the advantages and weaknesses of those types. Research Institute of water control of Czechoslovakia has developed its own bedload sampler, improving on Russian and Hungarian types. Author believes this device to be the most perfect sampler. S. Kolupaila, USA

1123. Pokhsraryan, M. S., On the velocities of flow which do not cause erosion (in Russian), *Izv. Akad. Nauk SSSR Ser. Tekhn. Nauk* **10,** 6, 85-89, 1957; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 2637.

An investigation is carried out to determine the velocities of flow which will not cause scouring in the particles of sediment lying in a sloping bank of a canal. In the equation for the computation, consideration is given to the lateral and lifting forces and to the forces of friction. As the result of the investigation on these lines a formula is obtained for the determination of the velocity on the bottom, v_{bot}, which is then brought into the mean velocities by the introduction of a coefficient $\zeta = v_{bot}/v_m$. Here the author follows the procedure proposed by I. V. Egiazarov [*Izv. Akad. Nauk Otd. Tekh. Nauk* no. 2, 93-108, 1956; *Dokladi Akad. Nauk SSSR (N.S.)* **107,** 4, 525-528, 1956] and therefore assumes that his solution holds good for any of Reynolds numbers. The author's assertion that his solution is true for curvolinear river beds is in no way to be understood from the deduction put forward by him, because in the equation for equilibrium no account is taken of the centrifugal forces acting on the particles of sediment. There are no experimental data in the paper to support the solution.

I. I. Levi

Courtesy Referativnyi Zhurnal, USSR

1024. Shifrin, K. S., Universal formula for the velocity of fall of a sphere in a liquid (in Russian), *Izv. Akad. Nauk SSSR Ser.*

Geofiz. no. 2, 280–282, 1958; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 2670.

Formulas are given which have been proposed by different authors for the determination of the velocity of fall of a sphere in a liquid. It is apparent that the method of calculation previously proposed by the author [*Trudi Gl. Geofiz. Observ.* no. 31, 1951] is far too unwieldy and that it can be appreciably simplified by recognizing that the most cumbersome portion of the calculations, due to the universality of the relation of the coefficient of the sphere's resistance to Reynolds number, can be carried out earlier in the procedure in a general form. The necessary computations are furnished and formulas, graphs and a table are provided to enable the calculations for the velocity of fall of a sphere in a liquid to be carried out rapidly. Yu. F. Dityakin

Courtesy Referativnyi Zhurnal, USSR

1125. Ivanov, P., and Sideras, Sh., Laboratory investigations on the appearance of losing substance in water-saturated sandy soils when subjected to impacts and vibration (in Russian), *Trudi Kaunassk. Politekbn. In-ta* **7**, 155–163, 1957; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 3087.

Results are given for the experimental investigation of the process of consolidation under the action of impact and vibration of water-saturated sands of various compositions. The tests were carried out on a vibrating table in a vessel 16 cm in diameter and 20 cm high. The measurements of the excess pressure in the interstitial water were carried out by means of special capacity and induction gages of a membrano·s type. The experiments established that one of the basic factors influencing the dimensions of the displacement of the mass of the water-saturated soil when in a state of dynamic consolidation (and, consequently the accompanying danger for building construction) is the continuous nature of the soil remaining in this dispersed state. This continuity depends essentially on the particle size of the granular material and the density of the soil texture, and also on the intensity and duration of the dynamic reaction. O. A. Savinov

Courtesy Referativnyi Zhurnal, USSR

1126. Adamov, G. A., Measurement of density and specific weight of suspensions, boiling layers, liquids and gases in ascending flow, *Measurement Techniques* no. 4, 426–433, Dec. 1959. (Translation of *Izmeritel'naia Tekbnika, SSSR* no. 4, 37–42, July/Aug. 1958 by Instrument Society of America, Pittsburgh 22, Pa.)

Two bodies of equal mass and equal fluid dynamic drag, but with different volumes, are submerged in the multi-phase medium whose density is to be determined. The difference in the upward thrust on the two bodies is readily related to the mean density of the medium. Because of the equal drag of the two bodies, the scheme will work in ascending flows as well as in stationary systems. It has application in fluidization, boiling, flotation, and other similar studies. C. L. Coldren, USA

1127. Foster, H. H., and Heidmann, M. F., Spatial characteristics of water spray formed by two impinging jets at several jet velocities in quiescent air, NASA TN D–301, 34 pp., July 1960.

Sprays formed by two 0.089-in. impinging water jets in quiescent air were studied, in the velocity range of 30 to 74 ft/sec, corresponding to that of current rocket engines. Atomizers were same as used in previous combustion tests. The point of jet impingement was surveyed photographically. Spray velocity varied from 99 to 72% of jet velocity in a circumferential survey around the point of impingement. One half of the mass was distributed within 40-degree included angle about the spray axis. Mass mean drop size was about 54% of the extrapolated maximum of 1800 to 2400 microns; the maximums occurred along the spray axis. Experimental apparatus is described; sample spray pictures are shown; typical spray distributions are represented in tables and charts. While this research itself was directed to clear up fuel combustion phenomena in rockets, the experimental method and equipment have a more general interest and applicability.

K. J. DeJuhasz, USA

1128. Benson, G. M., El-Wakil, M. M., Myers, P. S., and Uyehara, O. A., Fluorescent technique for determining the cross-sectional drop size distributions of liquid sprays, *ARS J.* **30**, 5, 447–454, May 1960.

Laboratory instrument and procedure for measuring the drop-size distribution of a fluorescent spray are described. A thin sheet of spray is illuminated with a mercury-arc lamp and photographed. Individual drops are then measured. Error in drop-size measurement is about 10% for 10-micron-diameter drops. This indeterminancy decreases rapidly for larger drops, but becomes very great for drops smaller than 5 microns. Authors discuss details of the fluorescent, optical and photographic problems encountered. Size-distribution data and photographs of drops are presented.

J. M. Pilcher, USA

1129. Lushevskii, A. S., The stability and the breakdown of a hollow jet of viscous liquid moving at small velocities (in Russian), *Izv. Vyssh. Uchebn. Zavedenii. Energetika* no. 3, 95–102, 1958; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 2672.

The problem described in the title is investigated theoretically; the jet is issuing from a sprayer. It is considered that capillary waves spread from both sides of the cylindrical film; the waves with increasing amplitudes reach the point leading to the breakdown of the film into separate annular segments which ultimately are reduced to drops. The author obtained an equation for the function of the current of the disturbed motion by starting from the Navier-Stokes equations and utilizing the method of small excitations. The particular solution of the author's equation can be presented as consisting of vortexless and vortex-containing portions. Continuing, the author obtained a transcendental equation linking the increment imposed on the jet of small excitations with all the parameters determining the breakdown of the jet; this was made possible by the author's use of the boundary conditions on the outer and inner free surfaces of the hollow jet. Because of the complexity of the transcendental equation obtained, the analysis was restricted to a single case of breakdown of the film. It was assumed that the forces of inertia of the liquid are small by comparison with the forces of viscosity and can therefore be disregarded. Only the long-wave vibrations are investigated. As the result of adopting these simplifications a quadratic equation is obtained for the vibrations increment and a formula is derived for the optimum length of the vibration wave, corresponding to the maximum increment. It is established theoretically that as the film gets thinner and as the viscosity of the jet diminishes the length of the vibration wave becomes smaller, corresponding with the maximum degree of instability. It is shown that, in consequence of the above, a hollow jet of liquid breaks down into smaller parts than a round jet. A formula is also obtained for the calculations of the portion of the jet which does not disintegrate.

Yu. F. Dityakin

Courtesy Referativnyi Zhurnal, USSR

Porous Media

(See also Revs. 592, 746, 1015, 1125)

1130. Rozenberg, M. D., Inflow of gas-impregnated oil to wells with pressure on the feed contour higher than the saturation pressure and with pressures on the face lower than the saturation pressure (in Russian), *Trudi Vses. Neftegaz. Nauk-i. In-ta* no. 12, 151–165, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5309.

The problem is investigated of the axisymmetrical inflow of gas-impregnated oil to wells, the oil having been displaced by water. The conditions of working are investigated, these enabling the oil to be de-gassed in the stratum, not over the whole stratum occupied by the oil but only in the inner portion adjoining the face of the well. In this area there is room, in consequence, for the motion of the gas-liquid mixture, at the same time when in the area adjoining the region, occupied by the boundary water, pressure is being maintained at a higher level than the saturation pressure and a flow of homogeneous oil takes place. The gas factor (that is the relation of the total volume of free and dissolved gases to the volume of de-gassed liquid) in this region of motion of homogeneous oil is a constant, which is also the case along the isobar $p = p_s$ (p_s being the saturation pressure). The application is the investigation of the method of changing the stationary states results in acceptance of the gas factor as a constant for the whole time of working of the whole stratum. In the investigation under consideration the case is examined of the constant values of the pressure on the feed contour and on the face of the well; as a consequence of this the situation of the isobar $p = p_s$ determines, in a well-defined form, the solution in the region between the well in this isobar, when in the region between the latter and the feed contour the solution depends on the position of the front of the water being displaced as well; for the finding of the relation between the radii of this front and the isobar $p = p_s$ an ordinary nonlinear differential equation is obtained in the study, which is capable of numerical integration. This equation was obtained for cases of piston-like displacement of oil by water and for approximate consideration of incomplete displacement, on the assumption of the constancy in the whole region of the displacement of the residual oil-saturated layer. Some results are also published in the paper of numerical calculations made and their analysis.

V. A. Arkhangel'skii

Courtesy Referativnyi Zhurnal, USSR

1131. Amelin, I. D., Determination of the parameters of strata by means of data obtained from the investigations of wells working at pressures lower than saturation pressures (in Russian), *Trudi Vses. Neftegaz. Nauk-i. In-ta* no. 12, 224–232, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5312.

An approximate method is proposed for the determination of the parameters of a stratum (permeability and fictitious viscosity) when the wells are being worked on a regime of dissolved gas. In this process a partial account is taken of the relation between the coefficient of the oil's viscosity, the volumetric coefficient and the pressure. It is assumed that the viscosity of the oil and the volumetric coefficient taking part in the expression for the difference in Khristianovich's functions are constant and are determinable by the mean pressure in the interval between the face and contour pressures. In addition, it is also assumed that the motion of the gas-containing liquid is steady, and that the gas factor is constant. A procedure is put forward for the calculation of the difference in Kristianovich's functions in the given premises, this procedure making it imperative to have available the results of supplementary investigations for the gas factors, the relation of the viscosity of the oil, the volumetric coefficient and the pressure, and the viscosity of the free gas in the conditions prevailing in the strata. It is shown that the examples given of the calculations by this method and by a more precise method available [see L. A. Zinov'eva, *Tr. Vses. Neftegaz. N-i. In-ta*, no. 6, 240–243, 1954] gave a divergence of up to 10% when the difference in pressure between the stratum pressure was below that of the saturation pressure by 33–37%, and of the face pressure—by 45–55%. The difference sought enables the permeability of the stratum to be found from Dupuis' formula. It is also shown that by means of investigation of the wells' inflow at steady rates of separation it is possible to determine the coefficient which takes into consideration the drop in the phase permeability when the gassified oil is being displaced by marginal water; a method is put forward to deal with this type of calculation, which enables the fictitious viscosity of the system to be found.

V. N. Nikol'skii

Courtesy Referativnyi Zhurnal, USSR

1132. Nasyrov, R. M., An approximate method for the derivation of functions of pressure in heterogeneous strata (in Russian), *Ucb. Zap. Kazansk. In-ta* **117**, 2, 125–129, 1957; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 2800.

A plane flow of an incompressible liquid is filtered through a porous soil in conformity with d'Arcy's principle. The process is described by a system of equations

$$v_x = -\frac{k}{\mu}\frac{\partial p}{\partial x}, \qquad v_y = -\frac{k}{\mu}\frac{\partial p}{\partial y}, \quad \frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} = 0$$

where v_x, v_y are the projections of the velocity v on to the coordinates axes, p is the pressure, μ is the viscosity of the liquid, k is the permeability of the soil,

$$\mu = \text{const}, \quad k = k(x, y), \quad \mu > 0, \quad k > 0$$

A solution for the system is sought with the conditions that p = const on the boundary of the region of filtration D and that p only has a finite number of special points in D and, moreover of such a nature that

$$\int_{l_i} \frac{\partial y}{\partial n}\, ds = Q_i$$

where Q_i are the assigned actual numbers, while l_i is an arbitrary contour taking in an adequately small vicinity A_i. The general case with the aid of the conforming reflection merges with the case of the unitary circle. The solution is obtained by the iteration method. Every stage in iteration requires the solving of Dirichlet's problem. The solution, as pointed out by the author, is made each time in elementary terms. The example furnished indicates the good convergence of the process.

N. V. Lambin

Courtesy Referativnyi Zhurnal, USSR

1133. Nasyrov, R. M., Determination of the heterogeneity of a stratum by the hydrodynamical method (in Russian), *Ucb. Zap. Kazansk. In-ta* **117**, 9, 133–138, 1957; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 2801.

The same filtration problem is investigated as in the author's previous work [see preceding review] with the difference that the power of the stratum is taken to be equal to b, and not 1, while pressure p is assumed to have only one special point (well) in the middle of a circular region of filtration D. The problem is to find approximately the permeability parameter of the stratum $\sigma(x,y) = \frac{b}{\mu} k(x,y)$ when the pressure on the periphery of circle D is known and in a certain finite number of points inside D, and also the yield of well ζ_0 and the mean value of the pressure on a certain assigned area with its center ζ_0. On the assumption that

$$\sigma(x,y) = \sigma_0 \exp \sum_{i,j}^{m} a_{ij} x_i y_i$$

the author obtains a system of algebraical nonlinear equations for the determination of the coefficients and indicates the iterational method for its solution. Each step in iteration involves the solution of a system of n linear equations.

N. V. Lambin

Courtesy Referativnyi Zhurnal, USSR

1134. Nasyrov, R. M., A method for the restoration of the function of pressure in a heterogeneous porous medium (in Russian), *Izv. Vyssb. Ucbebn. Zavedenii. Matematika* no. 1, 114–123, 1958;

Ref. Zh. Mekh. no. 3, 1959, Rev. 2802.

The study concerns the same filtration process referred to in the author's previous work [See Rev. 1132 above]. A pressure function is sought with a given pressure operating on the boundary of the filtration region (problem A) or the pressure on the face (problem B). The iterational method is investigated as described in the work referred to above for the solution of problem A. An approximate solution is given for problem B by merging it with problem A.

N. V. Lambin

Courtesy Referativnyi Zhurnal, USSR

1135. Strezhnev, V. A., Determination of the field of pressure in a stratum with consideration for the transition zone (in Russian), *Uch. Zap. Kazansk. In-ta* **117**, 9, 104–109, 1957; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 2805.

The problem is examined regarding the steady distribution of pressure in a stratum under pressure where there are two zones of water and of petroleum and a transition zone, separated by closed, smooth nonintersecting contours. A solution is proposed for a special case of the problem, when both the contours take the shape of concentric peripheries, while in the transition zone the coefficient of filtration changes along the radius in conformity with the linear principle. The pressure here is presented in the form of series of hypergeometrical and trigonometrical functions, while the resolution coefficients are determined from the conditions of the equality of pressure and yield on the boundaries of the division. A calculation formula is derived for the case of the work of a single well, situated in the center of the inner zone. In the general case of configuration of the zones the proposal is made to split up the transition zone by nonintersecting curves into parts and to assume that the filtration coefficient is constant in each of the parts. It then becomes necessary to solve a system of integral equations in order to find the pressure distribution. It is shown that a solution of the first problem on these lines leads to a system of algebraical equations. It should be noted that with the assignments for the filtration coefficient in the transition zone no real account is taken of the existing link between the coefficient of filtration and the petroleum-water saturation of the porous area of the stratum.

V. N. Nikolaevskii

Courtesy Referativnyi Zhurnal, USSR

1136. Saikin, S. F., An approximate determination for the location of the water-petroleum contact in dipping strata (in Russian), *Uch. Zap. Kazansk. In-ta* **117**, 9, 139–144, 1957; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 2806.

This is an investigation of the problem of the location of the water-petroleum contact in slightly dipping strata with a rigid water/pressure regime in operation. The difference in viscosity of the liquids and the phasal permeabilities are disregarded; it is assumed that the line of contact is straight and that the permeability of the stratum in the direction perpendicular to the stratification is infinitely great. A system of differential equations is derived and integrated in relation to the parameters characterizing the location of the water-petroleum contact, for cases of plane and axially symmetrical single-dimensional flows. This procedure was based on the equation of material balance for the whole of the stratum and its separate parts. The declination of the line of the water-petroleum contact from the horizontal is determined from the geometrical characteristics obtained.

V. N. Nikolaevskii

Courtesy Referativnyi Zhurnal, USSR

1137. Safronov, S. V., Transposition of the water-petroleum contact in dipping stratified layers at the limit of values for the vertical permeability of the rock (in Russian), *Trudi Vses. Neftegaz. Nauk-i. In-ta* no. 12, 120–139, 1958; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 2807.

Paper deals with the transposition of the water-petroleum contact in dipping stratified layers with consideration for the formation of a transition zone. The basis of the paper is the result of investigations made by A. M. Pirverdyan [*Prikl. Mat. Mekh.* **16**, no. 2, 1952] and I. A. Charno [*Izv. Akad. Nauk USSR, Otd. Tekh. Nauk* no. 4, 107–120, 1954] and the article is divided into two parts. In the first part the case is examined where the permeability in all the three zones is the same. The second part of the study corresponds to the case where the permeability in all the zones is different. In both parts of the study cases are sought for zero and infinitely large permeability of the stratum in the direction perpendicular to the stratification. Numerical calculations are given and schematic outlines illustrate the movement of the division boundary of the two liquids in the cases mentioned.

M. V. Filinov

Courtesy Referativnyi Zhurnal, USSR

1138. Buzinov, S. N., and Charnyi, I. A., On the galloping motion of saturation during the filtration of two-phase liquids (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 7, 142–146, 1957; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 2808.

Deductions are put forward for finding the characteristics of a single-dimensional filtration of a two-phase liquid, the tube having a constant section and the forces of gravity being taken into consideration. The velocity of the motion of the rapid change in saturation is recorded by means of the equation for the equilibrium of mass for this change. It is shown that for the case of a constant initial state of saturation the second value for the saturation in the change increases up to the determined value ("frontal" saturation) and then remains constant. A method is given for the determination of this frontal saturation. A procedure is proposed for carrying out the general investigation of the rapid changes in accordance with the known initial distribution of saturation on both sides from it using the initial magnitude. With constant saturation on one side of the rapid change the differential equation obtained can be integrated in closed form. A graphical method is indicated for finding the rapid change obtained from the equilibrium of one of the phases of the change. The problem is investigated of the formation of a petroleum bubble in the water-saturated stratum.

V. N. Nikolaevskii

Courtesy Referativnyi Zhurnal, USSR

1139. Buzinov, S. N., The parameters of similarity when one liquid is being displaced by another and the influence of yield on the petroleum output (in Russian), *Izv. Vyssb. Uchebn. Zavedenii. Neft'igaz.* no. 1, 81–85, 1958; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 2809.

Differential equations are examined for the motion of a two-phase incompressible liquid, account being taken of the capillary forces involved. The phase permeabilities and the capillary pressure are taken to be assigned by the empirical functions of saturation. After the equations had been brought to the dimensionless form a number of dimensionless parameters were established; the influence of these on the petroleum output is discussed.

I. A. Charnyi

Courtesy Referativnyi Zhurnal, USSR

1140. Warren, J. E., and Hartsock, J. H., Well interference, *J. Petroleum Technol.* **12**, 9, 89–91 (Tech. Note), Sept. 1960.

An asymptotic solution to the equation that describes the flow of a slightly compressible fluid in an infinite porous medium has been used to estimate the interaction between two adjacent wells producing from a common reservoir. A direct method for approximating the interference time defined by Stevens and Thodos has been suggested. An alternative definition for the time of interference, based on the minimum pressure change in the interference region, has been proposed; also, a direct method of determination has been prescribed. Examples have been employed to illustrate the use of both methods.

From authors' summary

1141. Balakrishna, S., and Narayana, G. S., A simple method for measuring porosity in rocks, *Proc. Indian Acad. Sci.* (*A*) **51,** 5, 265–269, May 1960.

1142. Gaucher, D. H., and Lindley, D. C., Waterflood performance in a stratified, five-spot reservoir—A scaled-model study, *J. Petroleum Technol.* **12,** 9, 208–215, Sept. 1960.

Geophysics, Hydrology, Oceanography, Meteorology

(See also Revs. 738, 743, 841, 919, 981, 982, 1090, 1100, 1153, 1162)

1143. Sager, G., Anniversary of tide calculating machines (in German), *ZAMM* **39,** 3/4, 110–117, Mar./Apr. 1959.

Principles of tide-predicting machines based on nonharmonic and harmonic calculation means are reviewed. The construction of the latest harmonic type, the 25th in the world, is described. It has 34 components, with epoch deviation from astronomical data of less than 10^{-7} deg/hr. Tide heights are predicted correctly to 5 cm for a total change of 6 m. V. Salmon, USA

1144. Sinha, G., Methods of mathematical computation for tidal rivers and their application as practised in the Netherlands, *J. Instn. Engrs., India* **40,** 9 (Part 1), 556–570, May 1960.

In The Netherlands, most of the hydraulic projects are concerned with tidal rivers and tidal basins. Large tracts of land have been or are being reclaimed from the sea on a national basis, and particular attention is being given to the mathematical analysis of the tidal mechanism and to the evolution of methods of tidal computation with the help of suitable approximations to the channel contour. This paper gives a short survey of the development of these methods and their utility and applications. Dronkers' method of successive approximation is discussed in detail.

From author's summary

1145. Krylov, Yu. M., The statistical method and calculation for ocean wind waves, Part 2 (in Russian), *Trudi Gos. Okeanogr. In-ta* no. 42, 3–88, 1958; *Ref. Zh. Mekh.* no. 2, 1959, Rev. 1429.

In chapter I of the monograph the equations derived in Part I of the communication [see *Tr. Gos. Okeanogr. In-ta* no. 33 (45), 5–79, 1956] are applied to the calculation of the growth or extinction of wind waves in the storm's region. For the mean values of elements, for instance for $\bar{\beta} = \bar{c}/V$, the mean increment of the wave growth ($\bar{c}$ being the mean phase velocity, V the velocity of the wind gradient), $\bar{\delta}_1 = \bar{b}_1/\bar{\lambda}$ the mean steepness of the wave ($\bar{b}$ being the mean height of a 3-dimensional wave) $\bar{\lambda}$ the mean length of the wave, $\bar{L}$ the mean length of the crest, four equations were obtained. This closed system is supplemented by similarly derived expressions for the functions of distribution of probabilities, enabling one to ascertain the mean values for wave elements having the given probabilities. As the result of excluding from the first two equations the values $\bar{\delta}_1$ and $\bar{\beta}$ a linear heterogeneous differential equation is obtained with particular derivatives of the first order having independent variables $\bar{X} = gx/V^2$ and $T = gt/V$, (g being the acceleration of the force of gravity, x the length of scatter, t the period of the wind's action). This equation is integrated with the following initial and boundary conditions:

$$\bar{\beta} = 0 \qquad \text{when } T = 0,\ \bar{X} > 0 \qquad [1]$$

$$\bar{\beta} = 0 \qquad \text{when } \bar{X} = 0,\ T > 0 \qquad [2]$$

The relations obtained as the result of integration are presented in the form of two nomograms. In the system being examined only one equation is a differential equation, the rest—algebraical and transcendental; their application is also provided for by nomograms. Examples are given to illustrate the practical application of the computation method. Using a large and varied mass of experimental material a check was carried out of the results of the theoretical calculations, which gave a positive evaluation for the method. Chapter II of the publication deals with the study of storm-induced wind waves in shallow seas. In this case the author makes use of the same theoretical methods and follows the same sequence as he did for deep-water seas. A study was also made of the propagation of wind waves passing from a deep water sea to a very wide shoal-water shelf. A brief exposition is given in Chapter III of Pearson's method for investigating the wave-swept surface of the sea, which is based on the application of the concept regarding the spectrum of wave energy. Indications are furnished of how to apply this method for solving some problems which cannot be handled by the other means referred to in the paper under review. Ya. I. Sekerzh-Zen'kovich

Courtesy Referativnyi Zhurnal, USSR

1146. Kononkova, G. E., and Kontoboitseva, N. V., Fluctuations in temperature in the surface layer of the sea, caused by the action of waves (in Russian), *Izv. Akad. Nauk SSSR Ser. Geofiz.* no. 12, 1478–1483, 1957; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 2588.

Results are furnished for the simultaneous measurements in the surface layer of the sea of the fluctuations in the temperature, its vertical gradient, the velocity of the current, the height and periodicity of the waves. The observations were made in 1955 in the Black Sea section of the Marine hydrophysical institute. The recording apparatus for the temperature and pressure was placed in the sea at a depth of 1m, side by side. The results of the observations confirmed the existence of a connection between the temperature fluctuations and the pressure. The mean period of the largest fluctuations of temperature was close to the mean period of the waves. According to S. V. Dobroklonskii the observed connection between wave action and temperature is to be explained by the orbital motion of the particles of water in the wave. The curves for temperature fluctuations and for wave pressure are found to be in the same or in opposite phases in relation to the temperature gradient. Tables are given which confirm the deductions made. S. S. Voit

Courtesy Referativnyi Zhurnal, USSR

1147. Trupl, J., Relationship between intensities of short duration rainfalls and occurrence of thunderstorms (in Czech), Výzkumný Ústav Vodohospodárský, Práce a Studie Praha no. 100, 47 pp., 1959.

A linear empirical formula is derived which expresses the intensity of a 60-minute rainfall of certain frequency as a function of the mean annual precipitation during thunderstorms. Possibility of extrapolation of the rainfall intensity data is discussed for locations where these data are not available.

S. Kolupaila, USA

1148. Kao, S.-K., Transfer of momentum vorticity and the maintenance of zonal circulation in the atmosphere, *J. Meteorol.* **17,** 2, 122–129, Apr. 1960.

A theoretical, analytical treatment of atmospheric fluid mechanics employs vector analysis and the vorticity form of the equation of motion. Work is of an enveloping nature and connected with current studies of the general circulation of the earth's atmosphere. It has no significance in engineering.

A. S. Andes, USA

1149. Meyer, R. E., and Ho, D. V., Note on shock propagation in a stratified atmosphere, Brown Univ., Div. Appl. Math. Tr 35 (Contract Nonr 562(07)), 9 pp., August 1960.

A locally exact wave strength relation is given for the propagation of a very strong plane shock into an atmosphere initially at

rest, and some of its implications are discussed. It contributes to the elucidation of Whitham's (1958) rule and its background, and furnishes the first-order correction to that rule for the early stages of the motion in those cases where the rule is not initially exact.

From authors' summary

1150. Mikhnevich, V. V., Measurement of pressures in the upper atmosphere (in Russian), *Uspekhi Fiz. Nauk* **63**, 1 (b), 197–204, 1957; *Ref. Zh. Mekh.* no. 2, 1959, Rev. 1416.

A brief description of the apparatus used and the results obtained in the measurement of pressures in the upper layers of the atmosphere (50 to 100 km). In contrast with foreign experiments the measuring apparatus was placed not in the rocket itself but in a special container which broke away from the rocket at a predetermined height and continued in flight by means of inertia. The use of a container very markedly reduced the disturbing effects of the rocket on the medium (separation of the gas, destruction of the temperature consistency of the surrounding air, and so forth). As measuring instruments use was made of magnetic electrodischarging and thermal manometers. The manometers were conveyed into the air in sealed glass bulbs which were subsequently broken. An analysis of the data obtained showed that at an altitude of 85 km the pressure determined in the container (within the limits of measurement error) agrees with the values for the pressure obtained by measurement in the rockets. Above 85 km the pressure, measured in the container, is lower than that measured in the rocket, which might be explained by the influence of the dying out of the rocket itself. The distribution of the temperature in relation to the altitude is investigated; this is effected by computational methods with the aid of a barometric formula and the magnitude of the pressure taken from the experiment; a comparison is given of the results of the calculations with the data from foreign sources.

V. B. Cherenkov

Courtesy Referativnyi Zhurnal, USSR

1151. Dibai, E. A., The gravitational instability of a gaseous column (in Russian). *Astron. Zh.* **34**, 6, 954–956, 1957; *Ref. Zh. Mekh.* no. 3, 1959, Rev. 2414.

The problem is examined (within the framework of the theory of the small vibrations of a continuous medium) regarding the instability of an infinite liquid round cylinder of radius R with reference to its longitudinal disturbances, the cylinder being situated in the field of its own gravitational forces. The following equation is adopted in its completed form

$$\frac{\partial^2 s}{\partial t^2} = 4\pi G q s + c^2 \nabla^2 s \qquad \left(s = \frac{\delta q}{q}\right) \qquad [1]$$

where s is the density variation (condensation), ∇^2 is Laplace's operator, which is recorded in cylindrical coordinates. For the case of axial symmetry the solution is sought in the form

$$s = \varphi(r) e^{i\omega t - ikz} \qquad [2]$$

with the boundary conditions

$$s < \infty \text{ with } r = 0, \qquad s = 0 \text{ with } r = R_0 \qquad [3]$$

The author examines the particular solution

$$s = J_0\left(\frac{\mu_1}{R_0} r\right) e^{i\omega t - ikz} \qquad [4]$$

where μ_1 is the first root of Bessel's function. This is followed by the derivation of an expression for the velocity of propagation of waves along the axis of the cylinder

$$V = \sqrt{c^2 - \frac{4\pi G q}{k^2} + \frac{c^2}{k^2}\left(\frac{\mu_1}{R_0}\right)^2} \qquad [5]$$

Conforming with Jean's views, the author testifies to the setting-in of gravitational instability at a point where the velocity of the wave V [5] becomes an imaginary value. At this stage an expression is derived for the critical length of a wave λ_0, where λ_0 corresponds approximately to the distance between the centers of condensation into which the cylinder disintegrates. As an example an examination is made of a column in a gas-dust medium with a radius $R_0 = 0.1$ nc at a temperature $T = 5°$K.

A. K. Nikitin

Courtesy Referativnyi Zhurnal, USSR

1152. Dyubyuk, A. F., Determination of the wind and vertical velocity across the pressure field by means of three equations for the motion (in Russian), *Vestn. Mosk. In-ta. Ser. Matem., Mekhan., Astron., Fiz., Khimii* no. 4, 125–128, 1957; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5356.

An approximate method is proposed for the expression for the horizontal and vertical components of the velocity of motion of the air in the atmosphere across the pressure field. In contrast to the generally accepted simplifications in the equations for the motion along the horizontal, terms are retained containing the vertical component for the velocity; the equation for the motion along the vertical is recorded in a general form and does not merge with the condition of quasi-staticity; the equation for continuity is not brought in for investigation, and the density is replaced by a mean value. The method consists of a formal resolution of all the assigned and sought magnitudes into series in steps of some parameter ε, actually equal to unity. As the result, the nonlinear system of equations for the motion is converted into an infinite recurrent system of linear heterogeneous equations expressed in particular derivatives. For these equations solutions are worked out applicable to the assigning of initial fields of velocity in the whole of the semi-space $z > 0$ and their parity with zero on the boundaries of this semi-space (the initial and boundary conditions are not limited in the text, these can only be judged by the form of the solution). A separate examination is made of the stationary case. The convergence of the proposed method is not investigated. There is also nothing in the way of examples or analysis of the solution obtained.

L. S. Gandin

Courtesy Referativnyi Zhurnal, USSR

Naval Architecture and Marine Engineering

(See also Rev. 927)

Book—1153. Acevedo, M. L., and Mazarredo, L., edited by, Proceedings, Eighth International Towing Tank Conference, Madrid, Spain, 15–23 Sept. 1957; Madrid, Ministerio de Marina, Canal de Experiencias Hidrodinamicas, El Pardo, 1959, 347 pp.

Objectives of conference, attended by some 100 delegates from 21 countries, was the improving of ship model work and the reaching of agreement on basic procedures thereof. As at previous conferences [See AMR **9**(1956), Rev. 348] approach involved working sessions (five) at which formal committee reports summarized status and work in progress, followed by formal and informal discussions. They were preceded by an opening session and concluded by a closing session at which general decisions were reached. Proceedings are in English, with the technical decisions also presented in French, German, and Spanish. Committee reports with appendices run from 3 to 18 pages, formal discussions up to 135 pages, and the informal ones not more than 7 pages. Quite a few of the formal discussions are excellent technical papers on significant work done and are of great value in themselves.

Discussions and decisions on the five basic subjects were as follows:

Scale effects on propellers and self-propulsion factors. Committee report noted a number of scale effect researches on geosim

series and considerable work on wake and thrust deduction but a lack of uniformity in predicting ship power from model tests, Conference decisions recommended efforts to reduce number of procedures used in conducting and analyzing propulsion experiments and estimating ship performance therefrom. Work on propeller scale effects and use of turbulence stimulation devices on model propellers was noted and continued vigorous pursuit of this was recommended.

Skin friction and turbulence stimulation. This most extensively discussed subject encompased three times as many pages (155) as any other. Formal discussions ranged from scholarly reviews of problems inherent in the scaling of model ship resistance to prototype, reports on the drag of similar models over a range in sizes, to papers on the flat-plate turbulent boundary layer. The principal decision in this area involved the skin friction line or relation to be used in extrapolating model results to prototype. Due to a strong feeling that this should have a Reynolds number basis, an interim model-ship-correlation line was chosen which is slightly above the Schoenherr (1932) line at Reynolds numbers below 10^9.

Propeller cavitation. Original concern of this problem was the comparative cavitation tests of propellers as a water-tunnel standardizing technique. Committee report included studies of correlation between slotted-wall and closed-jet tunnel tests, propeller tests in a ship tank with a tube surrounding the propeller to simulate closed-jet tunnel, and studies concerned with the proper measurement of the effective water speed in tunnel propeller tests. Formal discussions included additional results from the newer (slotted-wall) as well as conventional tunnels. Comment from Russian delegates indicated less divergence between ship-tank and water-tunnel tests than appeared from the committee report and other discussion.

Seagoing qualities of ships. Discussions of seaworthiness studies were concerned to a considerable extent with new facilities development. Committee report includes a fine bibliography on recent efforts (both in tanks and with ships) in this rather new field of ship hydrodynamics. Conference recommended interchange of personnel and information on test techniques in waves, the development of theoretical methods for design and evaluation of experiments, and the collection of data on sea and ship performance for correlation with models.

Forces and moments on ships in a seaway. This new subject to the conference series is well covered in committee report. Future consideration was placed under aegis of technical committee for preceding subject.

J. M. Robertson, USA

1154. Sayre, C. L., Jr., and Duerr, R. J., Boundary-layer investigation on USS Timmerman (EAG 152) (EX-DD828), David W. Taylor Mod. Basin Rep. 1170, 18 pp., Aug. 1960.

Results of velocity measurements in the boundary layer of USS Timmerman (EAG 152) are presented in this report. Measurements of velocities in the throat of the condenser scoop and the pressure drops across the condenser are also given. A generalized form of Prandtl's equation for the growth of the turbulent boundary layer on a flat plate is derived for use in estimating the boundary-layer thickness at large Reynolds numbers.

From authors' summary

1155. Sasajima, H., Takagi, M., and Tanaka, I., Theoretical research on frictional resistance of a flat plate of finite breadth and a circular cylinder in axial motion, *Technol. Rep. Osaka Univ.* **9,** 67–77, Mar. 1959.

Shown in this paper are two theoretical studies of three-dimensional frictional resistance phenomena: a flat plate as a function of its breadth, and a circular cylinder as a function of its transverse radius of curvature.

In the study of the resistance of the flat plate as a function of its breadth, the use of an elliptical coordinate system gives a successful comparison with experimental results.

In the study of the frictional resistance of a circular cylinder as a function of its transverse radius of curvature the results have been applied to the practical application of the determination of the frictional resistance of the hull of a ship. Here a great many assumptions and approximations are necessary.

E. K. Gatcombe, USA

1156. Karhan, K., The axial friction resistance of long cylinders in turbulent flow, *Inter. Shipbldg. Prog.* **7,** 66, 72–76, Feb. 1960.

Extrapolation of model-ship drag results to prototype is usually accomplished with the aid of flat-plate friction data. Author tackles question, inherent in this approach, of the effect of transverse curvature on the turbulent friction drag. Method employed is a generalization to other exponents and Reynolds-number ranges of L. Landweber's 1949 analysis [AMR **3**(1950), Rev. 1199] based on seventh-root turbulent velocity-profile law. Nikuradse's smooth-pipe universal velocity-distribution law (semilogarithmic) is used to obtain other power laws applicable at other Reynolds numbers. Solution assumes that flow in boundary layer can be interpreted from pipe results by merely replacing pipe radius with boundary-layer thickness. Results of analysis indicate decreasing curvature effect at higher Reynolds numbers.

The analysis and its results are questionable and may be no improvement over Landweber's expectation that the seventh-root power-law analysis would indicate the relative effect at other Reynolds numbers. It is unfortunate that author did not employ a more modern velocity profile relation, since improved analysis of Nikuradse's smooth-pipe measurements have been available for some time. These indicate the need for considering a two-region analysis of the profile [cf. D. Ross, AMR **7**(1954), Rev. 562] and the use of different constants in the profile relations for the outer part of a boundary layer from those pertinent to the core region of a pipe. The early assumption of Prandtl and von Karman in 1920–1930, that the turbulent velocity profile was the same in a boundary layer as in a pipe of radius equal to the boundary-layer thickness, has been shown to gloss over vital differences and yield gross divergences in significant effects.

Author is in error in his reference to Nikuradse's work (this should be "Gesetzmassigkeiten der Turbulenten Stromung in Glatten Rohren," VDI Forsch. no. 356, 1932; with no NACA translation).

J. M. Robertson, USA

1157. Tasai, F., On the damping force and added mass of ships heaving and pitching, *Rep. Res. Inst. Appl. Mech. Kyusbu Univ.* **7,** 26, 131–152, 1959.

When cylinders of Lewis form sections heave and pitch on the free surface, their damping force and the added mass are exactly calculated by Ursell's method. Many figures in this paper show the results of the calculation. Then the author calculates, applying the results of the aforementioned calculation and by strip method, the damping force and the added mass of the two ships which were put to test, respectively, by Golovato and Gerritsuma. The added mass and the added moment of inertia which the author gained by strip method show good coincidence with the results of Golovato's and Gerritsuma's experiments.

To better estimate the damping force by strip method, it is necessary to calculate more closely the three-dimensional effect, nonlinear effect, etc. As to the added mass the three-dimensional correction could be negligible for most cases.

From author's summary by C. E. Carver, Jr., USA

1158. Kolberg, F., The wave resistance of ships in shallow water (in German), *Ing.-Arch.* **27,** 4, 268–275, 1959.

The effects of viscosity and finite depth are both included. The motion is steady relative to axes moving with constant speed. The equations of motion are the linearized Navier-Stokes equations, and the solution is given in the form of multiple integrals for the velocity components. Two problems are solved. First the wave mo-

tion due to a distribution of sources over a moving vertical plane is studied. (In inviscid flow this corresponds to a Michell ship of infinitesimal thickness.) Here additional boundary conditions are imposed on the bottom and the free surface but not on the moving plane. Next the wave motion due to a moving pressure distribution at the free surface is studied both in two and three dimensions. No asymptotic developments or numerical results are presented.

F. Ursell, England

1159. Marks, W., An experimental study of ship motions, Woods Hole Oceanographic Instn., Woods Hole, Mass. (ONR contract Nonr-1168 (00)), 35 pp., July 1960.

A linear theory of ship motion prediction was presented by St. Denis and Pierson in 1953. Present report describes an attempt at experimental verification of the theory, for pitch and heave, in head and following seas. Also considered are the improvements due to inclusion of certain coupling terms in the equations of motion as presented by Korvin-Kroukovsky. The pitch and heave of the Woods Hole Oceanographic Institution launch RISK (36 feet long) were recorded for a specific set of test conditions and analyzed in terms of the energy spectra of these motions. Also, from the physical and geometrical properties of the vessel, the particular amplitude response operators in these degrees of freedom were computed with and without the assumption of coupling, and, finally, the corresponding two sets of motion spectra were computed. The observed spectra were compared to the two computed sets of spectra. It was found that: (1) the linear prediction scheme given by St. Denis and Pierson agrees reasonably well with observation, (2) the improved response operators of Korvin-Kroukovsky yield motion spectra which in general agree more nearly with observation. The improvement due to inclusion of the coupling terms is demonstrated in graphs of comparison. From author's summary

1160. Becker, L. A., Structural evaluation of hydrofoils of Gibbs & Cox boat Sea Legs, David W. Taylor Mod. Basin Rep. 1401, 20 pp., July 1960.

Strains were measured in the hydrofoils and struts of the Gibbs & Cox boat SEA LEGS for known static loads, for operation in calm water under steady-state conditions and forced maneuvers, and for operation in 5-ft waves. Underway loads and load factors were determined. Experimental and theoretical stresses were compared. Motions and accelerations of the boat were also measured during the underway trials. It is concluded that the hydrofoil system is adequate to withstand the stresses resulting from operation in waves up to 5 ft in height at speeds up to 23 knots.

From author's summary

1161. Wetzel, J. M., Experimental and analytical studies of the longitudinal motions of a tandem dihedral hydrofoil craft in regular waves, Univ. Minn., St. Anthony Falls Hydraulic Lab., Tech. Pap. 30, Ser. B, 54 pp., Apr. 1960.

Experimental investigations were conducted with a tandem surface-piercing hydrofoil configuration free to heave and pitch in regular waves. Towing velocities of 5 and 10 fps were used in head and following seas. Tests at the lower velocity were conducted to check data previously reported by Leehey and Steele; the agreement was satisfactory. The data are compared with nonlinear and linearized theory developed by Ogilvie for both quasi-steady and unsteady conditions. The oscillatory heave, pitch, and phase relationships in general agree well with solutions based on the linearized equations. Consideration of unsteady effects in most cases improves the correlation between theory and experiment. The primary effect of the nonlinearities was in the existence of steady components of heave and pitch. The theoretical components are verified qualitatively by the experimental results.

From author's summary

1162. Cummins, W. E., On ship model testing for the prediction of extreme conditions in confused seas, David W. Taylor Mod. Basin Rep. 1410, 22 pp., Aug. 1960.

The problem is considered in which information is needed as to the nature of extreme conditions a ship is likely to encounter during a definite short period of operation in a well-defined random sea. Various model experiments are designed which are of increasing complexity and validity, each being an "optimum" design for a given degree of sophistication. The approach is based on the statistical properties of the ship-seaway system, and the resulting experiments are intended to provide a maximum of valid information from a small number of runs.

From author's summary

Friction, Lubrication and Wear

(See also Revs. 833, 978, 1115)

1163. DuBois, G. B., Ocvirk, F. W., and Wehe, R. L., Study of effect of a non-Newtonian oil on friction and eccentricity ratio of a plain journal bearing, NASA TN D-427, 43 pp., May 1960.

This reports what was likely the first methodical study of the effect of a polymer viscosity-index oil additive on sleeve bearing performance. Viscosities of the two test oils were taken from high shear rate capillary data. Although test results at 1000 to 8000 rpm with a 1⅞-in. journal and the corresponding short-bearing analysis were not conclusive, they suggested an improvement in load capacity relative to friction for the non-Newtonian oil.

E. R. Booser, USA

1164. Furuhama, S., A dynamic theory of piston-ring lubrication (2nd Report, Experiment), *Bull. JSME* **3,** 10, 291-297, May 1960.

The theory outlined in the author's previous publication [AMR 13(1960), Rev. 3207] was tested in an apparatus comprising a stationary piston and a driven cylinder. The piston ring was loaded hydraulically by a device that provided either static or dynamic load. Friction force between the piston ring and cylinder was measured by a strain gage and depicted by aid of an oscillograph. The piston ring load was varied from 0 to 50 Kg/cm², the temperature range was from 25° to 140°C, and the speed range was that provided by an engine crank having a stroke of 90 mm and revolving at speeds up to 1700 rpm.

The author based his claim for the confirmation of his theory on the agreement between the observed Stribeck plot and that calculated from his theory and the agreement between the calculated film thickness at failure and the measured surface roughness of the piston and ring. Reviewer believes that workers in this field will examine these results with interest for they are another indication that friction under conditions of mechanical constraint and moderate load can be represented by a viscosity-type function.

J. W. Givens, USA

1165. Sawyer, R. H., and Kolnick, J. J., Tire-to-surface friction-coefficient measurements with a C-123B airplane on various runway surfaces, NASA TR R-20, 32 pp., 1959.

An investigation was conducted to obtain information on the tire-to-surface friction coefficients available in aircraft braking during the landing run. The tests were made with a C-123B airplane on both wet and dry concrete and bituminous pavements and on snow-covered and ice surfaces at speeds from 12 to 115 knots. Measurements were made of the maximum (incipient skidding) friction coefficient, the full-skidding (locked wheel) friction coefficient, and the wheel slip ratio during braking.

From authors' summary

1166. Schey, J. A., The nature of lubrication in the cold rolling of aluminum and its alloys, *J. Inst. Metals* **89,** 1-6, 1960/1961.

Roll force and forward slip were measured over a wide range of first-pass reductions on 0.080-in.-thick 99.99% aluminum, Al-1.25% Mn alloy, clad and unclad Al-Cu-Mg-Si alloy, Al-5% Mg alloy, and mild-steel strips on a 14.3 × 24-in. two-high rolling mill at a rolling speed of 43 ft/min, using either a straight mineral or a compounded oil. The mean coefficient of external friction was derived from various equations based on forward slip and roll force. Although the numerical value of μ depended on the computing method, conclusions were qualitatively quite unambiguous. While μ was largely independent of pass reduction in the rolling of steel, it increased rapidly with roll pressure when rolling aluminum and Al-Mn alloy. The increase was less when a compounded oil was employed and was rather limited with strong alloys, especially Al-5% Mg alloy. This behavior is attributed to differences in the tendency of the rolled materials to weld to steel. The ease with which aluminum can be pressure-welded is assumed to lead to the formation of welded joints at the asperities of contacting surfaces, only partly prevented by boundary additives, and resulting in a marked rise of friction. The coefficient of friction was typically 0.035-0.045 for mild steel and varied from 0.02 to 0.3 for aluminum alloys. A very slight change from 3.0 to 1.8 μin. C.L.A. in the surface roughness of the rolls had a noticeable effect in reducing friction.

From author's summary

1167. Poletskii, A. T., Transient flow of a lubricant between two cylinders (in Russian), Designing and construction of machines, Chelyabinsk, 1957, 17-22; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5152.

The problem is investigated of the liquid friction in a full journal bearing of finite length. It is assumed that along the axis of the bearing there is in operation a certain amount of fall of pressure and that the layer of lubricant in the bearing is continuous. With the adoption of these assumptions the problem is solved in a variational setting. It is shown that the finding of a solution for Reynolds equation is the equivalent of the determination of that type of expression for the pressure in a layer of the lubricant at which the functional of differences between the dissipation function and the doubled momentary work of the forces of pressure and friction on the boundaries of the layer has a minimum value. The expression for the distribution of pressure is obtained in the form of a double trigonometrical series. The system of equations for the coefficients of the series, obtained from the conditions governing the minimum value for the functional, was calculated on a calculating machine. The relations for the distribution of pressures, the friction moments, the consumption of lubricant and the like are given in the form of curves, different lengths and eccentricities of the bearing being taken into account. It is shown that the amount of lubricant consumed in the bearing is determinable only by the geometry of the bearing and the fall of pressure along its axis.

A. I. Golubev

Courtesy Referativnyi Zhurnal, USSR

1168. Merrill, C. F., and Benzing, R. J., Solid-film lubricants for extreme environments, *Mach. Design* **32,** 23, pp. 208, 210, 212, Nov. 1960.

1169. Rolling bearing performance test for lubricating greases (The Mechanical Tests Panel of IP Standardization Sub-Committee D), *J. Inst. Petroleum* **46,** 442, 328-333, Oct. 1960.

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